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MONTANA HIGHWAY DEPARTMENT
LANDSLIDE RESEARCH PROJECT
PROGRESS REPORT

MARCH 30, 1967

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LANDSLIDE INVESTIGATION RESEARCH PROJECT

HPR-1(5) ITEM R-9

March 30, 1967

Prepared by

MONTANA STATE HIGHWAY COMMISSION

MATERIALS DIVISION

In cooperation with

U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

BUREAU OF PUBLIC ROADS

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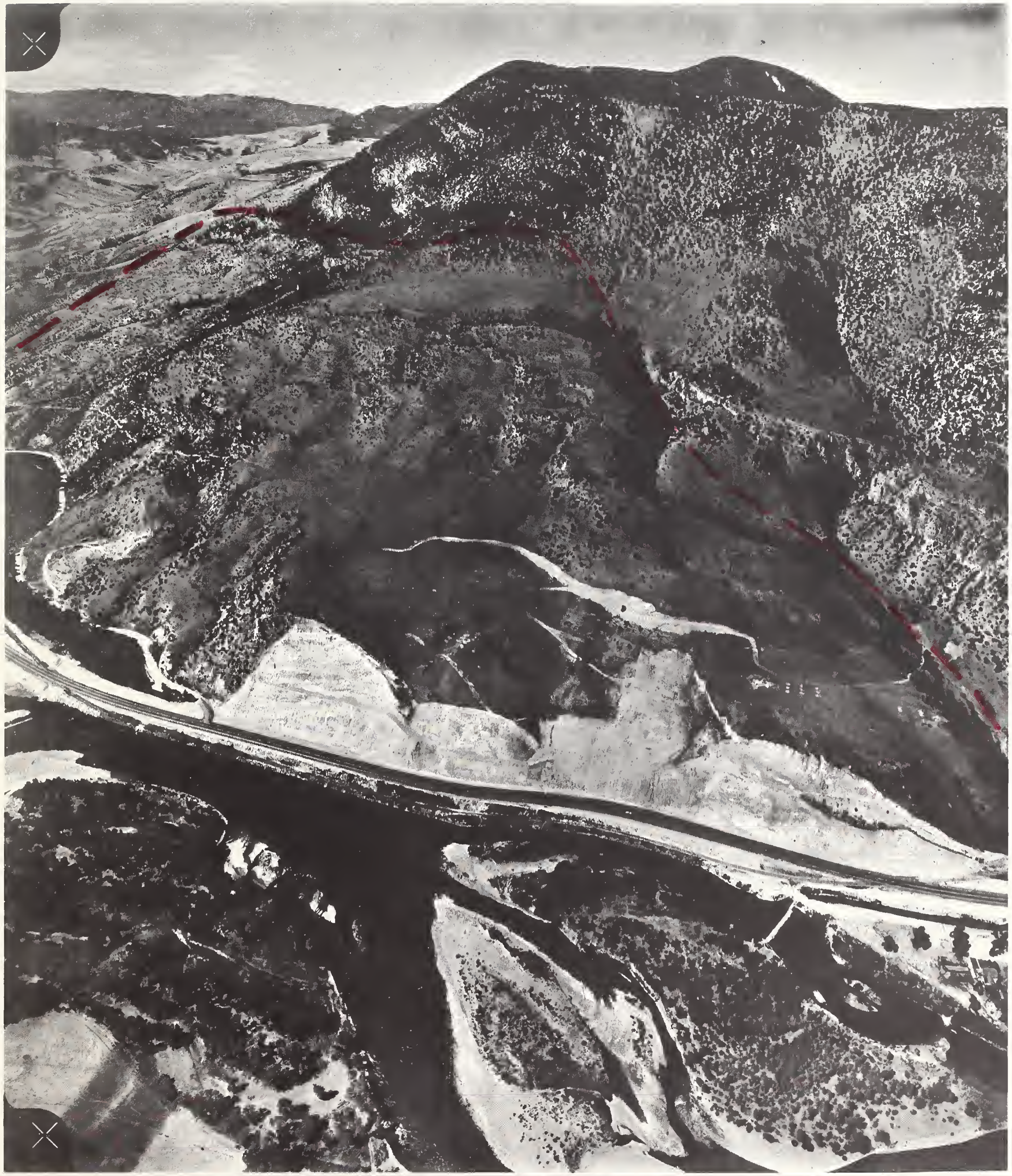


Oblique view looking south-west of entire landslide area. Note approximate outline of Pre-existing landslide marked in red. Details of existing failure zone are shown on blowup, Plate No. A

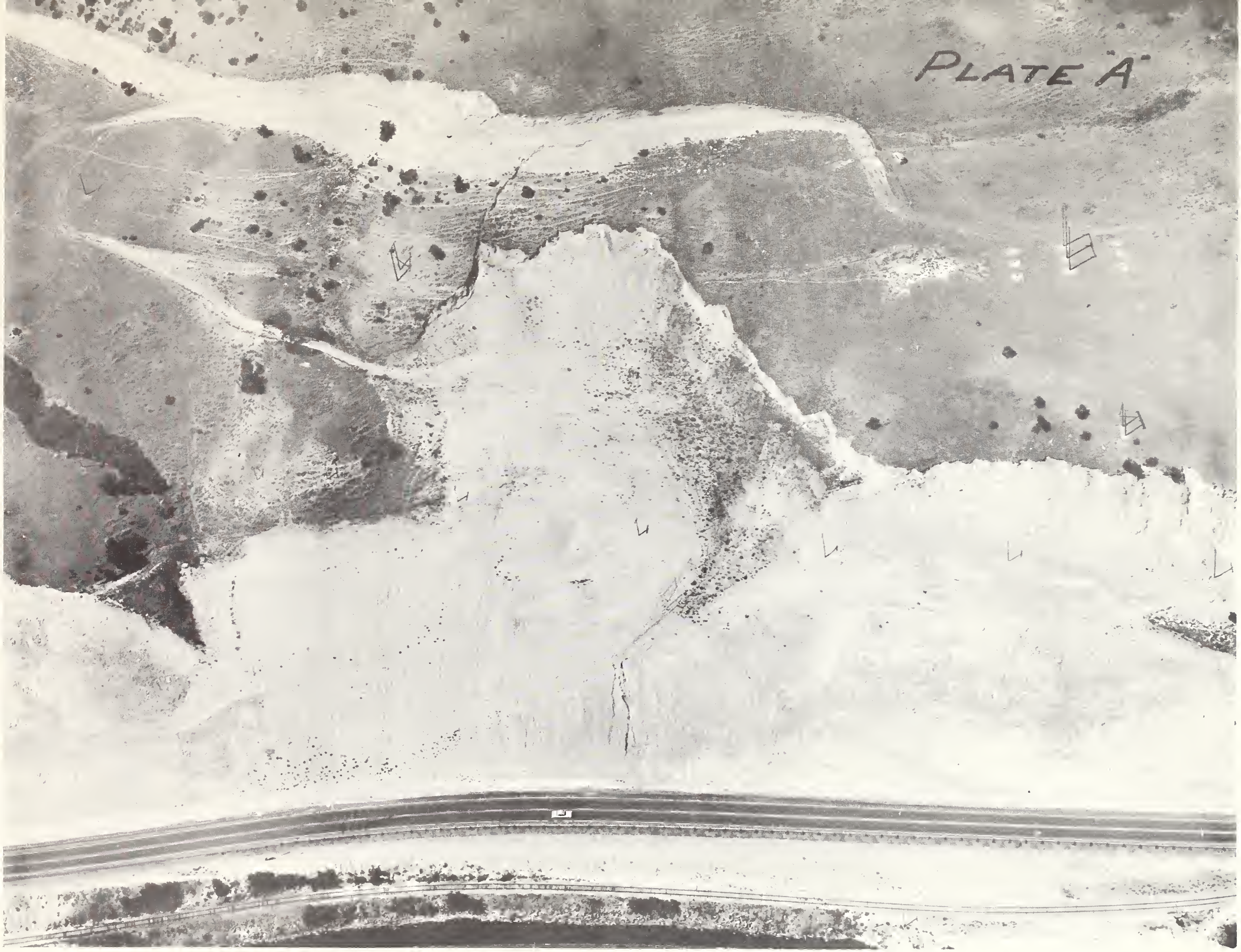


PLATE A

LANDSLIDE RESEARCH PROJECT

H.P.R.-1 (5)

Livingston Landslide

Investigation of the Livingston Landslide was initiated at the request of the Pre-Construction Engineer, on June 2, 1966 and with the approval of the Bureau of Public Roads on or about June 16, 1966.[5]

This report is a compilation of data concerning the Livingston Landslide obtained from our investigation as well as past studies.

HISTORY

The subject landslide occured during construction of Project F 217 (11), Gardiner - Livingston at station 1570±, approximately 5 miles south of Livingston, Montana. The major movement occured during the night of April 21, 1965 but tension cracks developed at least 4 months previously. The project was under construction and the contractor was engaged in excavation of the large cut sections in this vicinity when the failure occured. Subsequent remedial actions included the following:

A. Trenching to relieve pressure on a diversion structure in the Yellowstone River.

B. Relocation and regrading of the railroad bed.

C. Redesign of the cut slopes to remove driving weight.

D. Redesign of the railroad and highway grades and alignments to avoid cutting more than necessary into the toe area.

E. Establishment of a surface drainage ditch.

F. Drilling of horizontal holes into the landslide to attempt to drain

water from critical areas.

Investigation of the landslide during 1965 included the following: [1]

- A. Eight vertical drill holes in the slide area.
- B. Four horizontal drill holes in the slide area.
- C. Electrical resistivity profiles.
- D. Geologic mapping.
- E. Stability studies by the Butte District Geologist.

The remedial actions were sufficiently effective to allow completion of the project. (Refer to drill hole logs and resistivity data in the appendix to this report for 1965.)

During the spring and summer of 1966, some movement was noted by Division field personnel who initiated a request for further study. The current study was conducted during the late summer and fall of 1966, and included the following investigative methods:

- (a) Establishment of survey points to determine the rate and amount of movements.
- (b) The drilling of four additional vertical test holes to extend the information obtained during 1965.
- (c) Topographic mapping of the entire area of instability.
- (d) Geologic mapping of the general area.
- (e) Seismic study.
- (f) Resistivity study.
- (g) Stability Analysis.

The data obtained are further discussed in this report.

Various meetings with the Bureau of Public Roads personnel during November and December, 1966 disclosed that a wide variance of opinion existed as to whether or not the project should continue with investigation of the

Livingston Landslide. The only work on this project which has continued is the survey of the slide control points to determine movements and the preparation of this report.

Physiography and Climate

The landslide lies near the north edge of the Beartooth mountains, immediately west of the Yellowstone River.

The Yellowstone River flows north from Yellowstone National Park, turning east along the north slope of the mountains at Livingston, five miles north of the slide area. The landslide lies on an east facing mountain slope between elevations 4550 ft. and 6100 ft., with the original toe below the existing strand line of the Yellowstone River. The average rainfall at Livingston is about 15 inches (39 year record) with the month of May yielding the highest average moisture during the year. [2]

The Yellowstone River discharge at Livingston has averaged about 3600 second-feet of water for the 23 year record period. During the same period the maximum discharge of the Yellowstone River at Livingston was 30,600 second-feet on June 20, 1943 and the minimum discharge was 590 second-feet on January 22, 1940. [2]

Geology

The landslide lies just north of the Suce Creek thrust fault which dips toward the north under the landslide. In the immediate vicinity of the slide, the Cambrian age Grove Creek fm is thrust over the Cretaceous age Mowry fm. The upper plate of the thrust, bordering the south edge of the slide, has been folded and overturned toward the south. Thus the south edge of the landslide borders overturned Cambrian age rocks. Along the northwest and north edge of the landslide normal sections of Paleozoic rocks border the slide. These are generally dipping 15° to 26° toward the north or north-northwest.

The original landslides covered approximately one square mile and contained very large blocks of limestone together with rubble composed of crushed limestone, shale and large quantities of silt and sand sized, relatively non-plastic materials. Topographic study of the landslide seems to indicate that at least two large, semi-rotational movements have taken place in the past, each of which is characterized by large limestone blocks on the east edge, and relatively flat, hummocky ground in back of the limestone blocks toward the west. The head of the top slice lies at an elevation of about 6100 ft. with the toe at approximately 5300 ft.; the second slice lies between 5300± ft. and 4550 ft. The toe of the lower slice probably lies well below this mapped elevation. These slices become more confused toward the southwest. There are numerous small interior drainage areas on the surface and very poorly developed surface drainage patterns throughout the landslide. Several springs were found as shown on the topographic map.

Near the ridge tops at approximate elevations 5200 ft. and 5400 ft., many trees are bent outward and bowed toward the east. This has probably been caused by soil creep but the lack of developed surface drainage indicates that some if not all of the movement has taken place in recent time. Some evidence of a fault parallel to the valley bordering the landslide on the northwest was found but the fault could not be traced beyond the flat area at the head of this valley. Evidence seems to indicate that if this fault existed, the valley was developed prior to landslide activity inasmuch as it is the only well developed drainage in the landslide area.

The existing problem area is in the lowest original slide which probably extended well beneath the present river elevation. The large limestone blocks bordering the existing failure zone attests to this as they are part of the original landslide debris. During drilling in 1965 and 1966, a

remarkable lack of ground water was encountered. Some very small ponds of water were found within the sliding mass but the present water table is near the elevation of the Yellowstone River, as determined in the open holes A-1 thru A-4. (See drill logs A-1, A-2, A-3 and A-4).

Materials encountered in the existing slide are limestone rubble and silt, overlying shale. (See Laboratory Testing results in the appendix to this report). Several zones were encountered which are or have been sliding surfaces or faults. (Refer to drilling logs in appendix to this report).

Vertical drill hole No. A-4 was drilled 685 feet southwest of hole No. A-3 in a broad, shallow basin. No apparent movement has been noted in this vicinity within the time interval covered by this report. Surface features suggested that this basin-type area might be a natural drainage thus furnishing water to the present slide. This hole was drilled to a depth of 365.4 feet which is approximately 120 feet below river elevation and is the deepest hole that has been drilled on the slide. Silt, limestone and shale rubble was encountered to a depth of 48.1 feet. Between 48.1 and 257.8 feet the hole penetrated extensively fractured limestone with interbedded layers of siltstone and shale. The limestone is brecciated locally and probable slip zones or former slide planes were noted between depths of 89.5 and 96.0 feet, 160.0 and 198.0 feet, and 252.0 and 257.8 feet, respectively. Within these zones the hard, competent limestone occurs as angular fragments within a matrix of shale and/or clayey silt, locally this mixture is cemented forming a breccia. Below a depth of 257.8 feet an interbedded, dark gray-green shale and gray limestone was encountered to the total depth of the hole. Vertical bedding was noted at three different elevations in this material with a near horizontal attitude between these vertical zones. Occasional slickensides are also present. The attitude of the shale and limestone indicates that this material has been subjected to folding. Insufficient information is

available to indicate the nature and magnitude of this structure. Measurements made through perforated casing indicate the water level is at depth of approximately 241 feet which is near the elevation of the Yellowstone River east of the drill site. Warm springs adjacent to the east edge of the landslide attest to a probable deep seated disturbed zone. Alteration of the limestone blocks exposed in the cut sections north and south of the present landslide was caused by water, probably warm.

Landslide Discussion

The present landslide was triggered by construction of the highway as the pre-existing landslide toe was removed. While a major problem existed and does exist; it is apparent that the actual failure is a very small part of the pre-existing landslide zone. The portion which failed was saturated, at least in part, as witnessed by project, division and district personnel. Water and flowing silt was observed during and shortly after the failure at and near the toe area. Every indication points to a circular arc failure, as evidenced by the railroad displacement upward, and the shape of the failed surface. Some lower arcs developed, or the lower portion of the failure became planar because pressure was put on the diversion structure in the Yellowstone River well below and east of the major failure. Trenching between the slide and the concrete structure immediately relieved this pressure.

The landslide was described by the Resident Engineer, as follows:

> "The original movement, which produced a small 8" scarp occured on or about December 3, 1964, when the cut was almost to grade except for the north end. The cut slope remained static through the winter. On April 7, 1965, the roadway between 1574 and 1579 heaved 2 feet. On April 19, 1965, a small crack was noted in the roadway

> at the north end of the cut with a heave of about 6 inches.
>
> The major movement occured on April 22 & 23, 1965, and slowed on April 24th. The head of the slide moved vertically 6 ft. ± on the 22nd and 6 ft ± on the 23rd. The total lateral movement in the roadway was 30 ft. ± . The failure from station 1574± to 1576+50 was toward and nearly perpendicular to project centerline, while from 1576+50 to 1580± the movement was northeast at about an angle of 45° as measured from the roadway alignment. The Northern Pacific tracks were displaced approximately 8 ft. east and 2 ft. upward".

This landslide is presently moving very slowly with the movement again directly toward the highway as far as can be determined. Evidence of roadway heave has not been found to date although some movement has roughened the driving surface. The railroad grade has remained stable since the control points were established. The landslide head is migrating west and tension cracks have developed above the drainage ditch. The whole moving mass is bounded by visible cracks. Data pertaining to the rate of movement are included in the appendix to this report and later data will be available in the Bozeman Division office.

Laboratory Testing

Materials in the existing landslide were classified by testing as A-1-a to A-4 (8) with liquid limits of 17 to 34 and plastic indexes of NP to 9. Natural moisture contents ranged from 7.7% to 24.6%, well below the plastic limit in most cases.

Shear Testing results varied greatly, but in general the unconfined shear strength value obtained from samples in drill hole No. A-1 of 1033 lbs/ft^2 could be considered representative of the ultimate unconfined shear

strength. (Lab. No. 332941.) This shear strength value would approximate the strengths found in the silts encountered in test hole No. A-4 by direct shear tests. These gave average ultimate shear strengths of C=325 lbs/ft^2 with an angle of internal friction of 19.5°, at natural moisture contents. At saturation, the angle of internal friction would be lowered to about 10°. (Refer to Lab. No. 338457.)

An obvious shear plane was encountered at a depth of 165 ft. in test hole A-4. This hole is outside the existing failure but again indicates the deep seated nature of the original failures. Shear values here are 50#/ft.^{2}. (Lab. No. 338458.)

Quantitative analysis was utilized to determine if the limestone encountered in the test holes A-2 and A-3 were similar in composition. They were identified by visual inspection as being identical and the chemical analysis indicated the same. It was intended that this be carried further to determine the exact formation which each limestone block on the slide area represented and thus determine its relative displacement.

Resistivity Study-1966

On November 2 and 3, 1966, two electrical resistivity surveys were made within the slide area. The resistivity instrument was constructed according to BPR design but had never been operational. A representative from the BPR's exploration section familiarized the investigators with the instrument during the surveys and recommended some modifications to correct errors made during the initial assembly of the instrument and to allow longer electrode spacings to be used.

Resistivity test No. 1 was conducted near drill hole No. A-3 and the maximum spread of the electrode spacing was 78 feet. Utilizing Moore's Method of interpretation for the curve obtained in this survey, three points of tangential intersection were obtained. The depths obtained for the three breaks

in the curve do not correspond to a distinct lithologic change noted on the drill log. The increased resistance apparent on the curve at a depth of 16.8 feet may correspond to the change in relative density indicated by the penetrometer test between 16.5 and 20.7 feet or a change in moisture content. A lower resistivity was obtained below a depth of 32.2 feet. Shale is noted at a depth of 25.0 feet on the drill log. A possible slip zone composed of very soft clay extends from a depth of 73.0 to 78.0 feet. The resistivity survey did not indicate the presence of this zone.

The second resistivity survey was run near drill hole No. A-1. Three changes in resistance are noted at depths of 4.7, 27.7 and 49.1 feet, respectively on the curve. The two uppermost breaks do not correspond to a lithologic change as indicated by the drill log. However, the lower resistant material at 49.1 feet probably corresponds to the shale contact noted at a depth of 48.0 feet on the log.

Refraction Seismic Study

Seismic studies were undertaken prior to test hole drilling to determine where test holes should be drilled and to what extent this type of study could be used on this project. The results of this seismic study are summarized in Table "B".

The results of this geophysical study were as anticipated. The shale surface can be determined by this investigative method as can the dense limestone encountered in test hole A-2. Fractured limestone such as underlies seismic stations Nos. 12 and 13 seems to have about the same seismic velocity as the shale under test hole A-3. For this reason drilling would be required to determine which material underlies the surface silt and rock fragments in any extended study.

This investigative method will not find the sliding surface unless

this plane is directly over a material which possesses higher seismic velocity properties than the materials above the failure surface. This method is also restricted by depth limitations inherent in the equipment, and surface configuration of the area.

Stability Analysis

The stability analysis of any landslide is dependent upon the accuracy of determination of the following variables:

(a) Geometry of the failure and surrounding area.

(b) Water distribution.

(c) Physical characteristics of the materials involved.

(d) Nature and configuration of the failure surface.

The Livingston landslide is very complex because the existing failure zone is only a very small part of the pre-existing landslides. The materials involved in sliding are limestone rubble and silt. Shear strengths, in place density and natural moisture contents are completely dependent upon the relative amounts of silt and limestone fragments as well as the availibility of water in the form of rain and/or snow and are, therefore, almost indeterminate. Laboratory shear strengths determined from samples of the silt are probably not representative of the mass. The movements in the existing failure, may precipitate a much larger failure in the future. The existing shear failure has been progressively advancing the head toward the west. The shear strains are evidently developing slowly at the present time. Surface runoff is no doubt adding weight by changing the moisture contents and thus the unit weights of the materials in the slide.

The only possible approach to a stability study in this situation is to assume a dynamic condition, with a safety factor of under 1.00. In this manner it is possible to determine relative safety factors under certain

forseeable conditions. This is the type study herein presented. The following assumptions were used in this analysis:

(1) The failure approximates a segment of a circular arc.

(2) The in-place density is 130 lbs/ft.^{3}.

(3) The existing safety factor on the failing area is approximately 0.90.

(4) The shear strength values are fairly constant and will remain so in the forseeable future.

With these assumptions several cross sections and trial arcs were inspected. Of the cross sections studies, two were selected for further study as they appeared to be the most critical. (Refer to Sections E-EE & G-GG in the appendix to this report.)

Arc No. 3 in Section E-EE was found to have a safety factor of 0.901 using shear strengths indicated by testing, i.e. Cohesion = 325 lbs./ft.^{2} with a friction angle of 15^o. Arc No. 3 is believed to approximate the presently existing failure surface. The safety factor obtained bears out this assumption. It will be noted that arcs 4, 5 and 6 have lower safety factors. This is due to the geometrics of the area. The fact there has not been failure along these arcs indicates that either (1) higher shear strengths exist in the materials further west or (2) the so called "starting" friction has not yet been overcome. (Removal of more materials in the vicinity of drill hole A-3 would no doubt initiate this larger movement, if this is the case.) The safety factors were derived by the use of the following equation:

$$\text{Safety Factor} = \frac{\text{Resisting Forces}}{\text{Driving Forces}}$$

Where Resisting Force = $C + \sigma \tan \phi$.

C = Cohesion X Arc length

σ = Stress normal to the slip surface

ϕ = Angle of Internal Friction

Driving Force = Stress tangential to the slip surface.

A planar type failure was also studied through a cross section at station 1576+10. The assumed failure plane extends from the top of the limestone noted at a depth of 35.0 feet in drill hole A-2 eastward into the river. From the limestone contact in hole A-2, the planar surface extends 705 feet west to include the area bounded by arc No. 3 in the circular arc studies. The same strength parameters were used in this analysis as in the circular arc studies, namely $\phi = 15^{\circ}$ and 325 lbs./ft.^{2} cohesion. Using these values, a safety factor of 1.18 was obtained. This value is evidently too high because either; (1) the strength parameters used in the calculations are greater than the actual values or (2) the slip plane is not as assumed and the failure has not occured entirely along a planar surface. Another analysis was made using an angle of internal friction of 12° with the same cohesion value of 325 lbs./ft.^{2}. The lower friction angle reduced the safety factor to 0.993 for a planar failure. A failure surface 910 feet in length was used in both analyses.

Areas of Further Exploration

The steep slope at the head of the failing zone continues to add driving weight, as the materials move down and away from it. It is possible that a natural, as yet undetermined, barrier to head advancement may exist. This could only be determined by deep drilling. There is no assurance that this drilling will provide useable information but if money and time permit, drilling here may be of value.

Water was not encountered in the drilling and probably many test holes would be required to completely determine the ground water characteristics

in the area of the failure. The very large blocks of limestone north and south of the failing arc may be moving as evidenced by small changes in control points in this vicinity. If careful study determines this to be true, test holes in these areas may be required.

Several factors should be considered prior to a continuance of this investigation.

(1) The sliding planes have not been discovered. It is doubtful if the methods utilized will provide the exact configuration of these surfaces without additional equipment such as the slope indicator.

(2) The landslide is active and may become a major failure this spring as it did in 1965.

(3) Added investigation may cost a great deal of money with little benefit derived because of the complexity of the situation.

List of References

Ref. No. 1 "Report on Investigation of a Slide Area, Station 1580 to 1584", dated April 1965 by Mr. Richard R. Matthew, Butte District Geologist.

Ref. No. 2 "Geology of the Area East and Southeast of Livingston, Park County, Montana", U. S. Geological Survey Bulletin 1021-L 1957, by Mr. Paul W. Richards.

Ref. No. 3 "Geology of the Brisbin Quadrangle, Montana", U. S. Geological Survey Map Cq-256, by Mr. Albert E. Roberts.

Ref. No. 4 "Montana HPR-1 (4), Landslide Investigation Research Project, Item R-9", Memorandum from the Bureau of Public Roads, dated October 5, 1966, File 08-24.3.

Ref. No. 5 Various interdepartment memorandums dealing with requests for and approval of this study.

Livingston Landslide
H.P.R. -1 (5)
Aug. 2-4, 1966

Refraction Seismograph Data

Shot No.	Shot Location	Jug locations from shot point.	Layer No. 1. Velocity ft/sec.	Layer No. 1. Depth	Layer No. 2 Velocity ft/sec.	Layer No. 2 Depth	Layer No. 3 Velocity ft/sec.	Layer No. 3 Depth
1	Left ditch line, @Sta.1571+90	10'-30'-50'-70'-90'-110'-130'-150'-170'-190'-210'-230'- @Sta.1574+20	2350	0'to 6'	5000	6'to ?		
2	Left ditch line, @Sta.1574+30	10'-30'-50'-70'-90'-110'-130'-150' 170'-190'-210'-230'-@Sta.1572+00	2960	0'to 11.5'	4880	11.5' to 37'	10,000	37' to ?
3	On control line "B", Sta. 2+90	20'-40'-60'-80'-100'-120'-140'-160'-180'-200'-220'-240'- @"B".Sta. 0+50	950	0'to 14'	2420	14'to 31'	4070	31' to ?
4	On control line "B", Sta. 0+10	40'-60'-80'-100'-120'-140'-160'-180'-200'-220'-240'-260'- @ 2+70	1480	0'to 7'	2220	7'to 33'	4880	33' to ?
5	On control line "B",Sta. 3+30	60'-80'-100'-120'-140'-160'-180'-200'-220'-240'-260'-280'- @ 0+50	1330	0'to 21.5'	4140 ?	21.5' ?		
6	450' Lt. Sta. 1573+30	10'-30'-50'-70'-90'-110'-130'-150'-170'-190'-210'-230'-@450'Lt.1575+60	1330	0'to 6.5'	3640	6.5' to ?		
7	451' Lt. Sta. 1575+40	10'-20'-30'-40'-60'-80'-100'-120'-140'-160'-180'-200'- @450'Lt.1573+40	1250	0'to 4.0'	1620	4.0' 21'	4660	21' to ?
* 8	North end flat area, West of hole A-4	10'-30'-50'-70'-90'-110'-130'-150'-170'-190'-210'-230'- @ S40° W	1600	0'to 5.5'	2310	5.5' to ?		
* 9	20' S40° W from Jug No. 12 in shot 8	20'-40'-60'-80'-100'-120'-140'-160'-180'-200'-220'-240'- @ N40°E	1870	0'to 36.5'	5650	36.5' to ?		
*10	Same location as No. 9	20'-40'-60'-80'-100'-120'-140'-160'-180'-200'-220'-240'- @ S40°W	1520	0'to 39.0'	4810	39' to ?		

Livingston Landslide
H.P.R. -1 (5)
Aug. 2-4, 1966

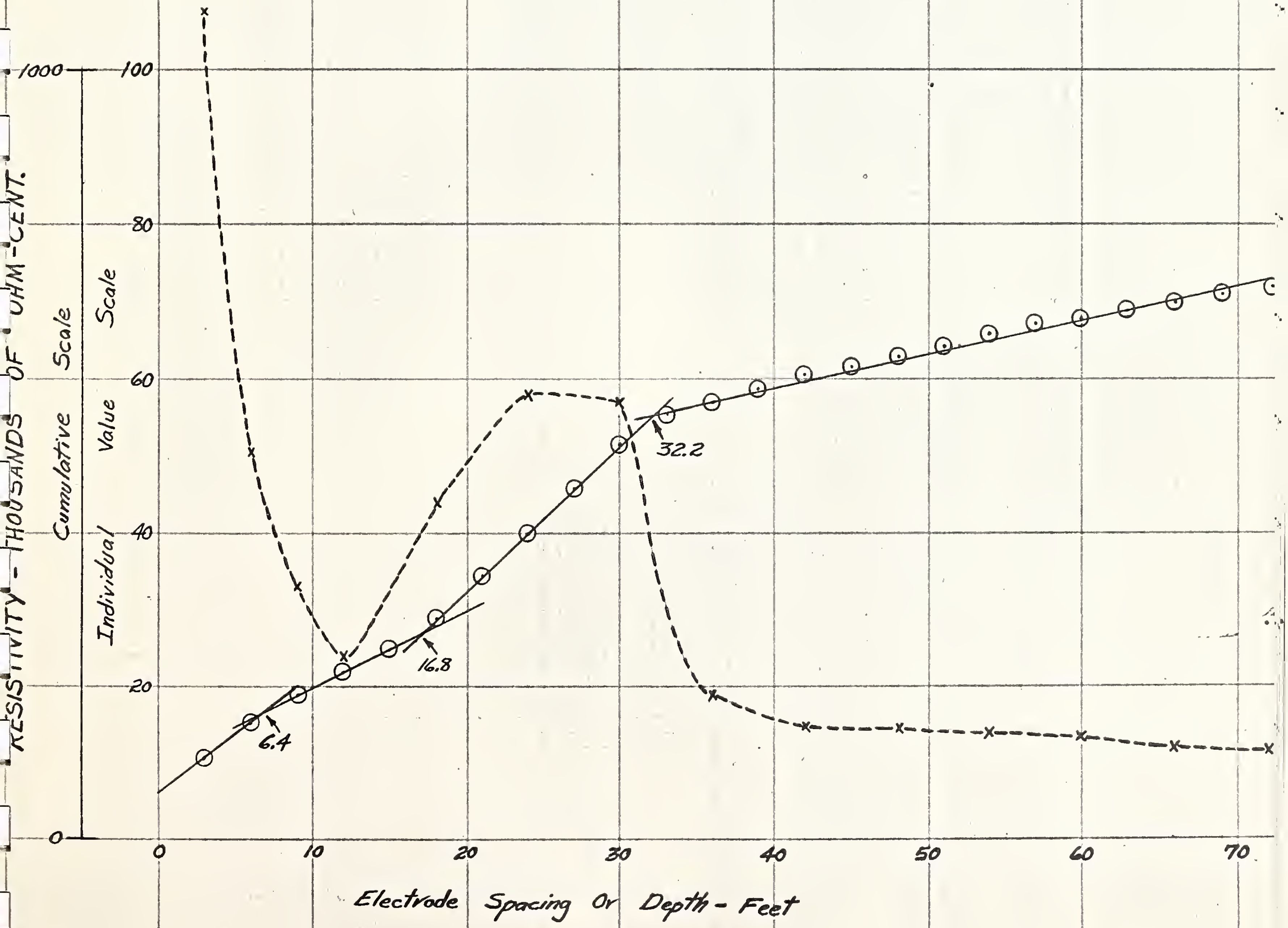
Refraction Seismograph Data

Shot No.	Shot Location	Jug locations from shot point	Layer No. 1		Layer No. 2		Layer No. 3	
			Velocity ft/sec.	Depth	Velocity ft/sec.	Depth	Velocity ft/sec.	Depth
*11	Reverse of shot # 10	20'-40'-60'-80'-100'-120'-140'-160'-180'-200'-220'-240'- @ N 40° E	2180	0'to ?				
* 12	Approx. 450' Lt. Sta. 1561+00	20'-40'-60'-80'-100'-120'-140'-160'-180'-200'-220'-240'- @ N 67°W	1330	0'to 15.2'	3860	15.2' to ?		
* 13	Reverse of shot # 12	20'-40'-60'-80'-100'-120'-140'-160'-180'-200'-220'-240'- @ S 67°E .	1600	0'to 5.5'	2910	5.5'to 12.0'	4000	12.0' to ?

* Locations shown on Plate No. 2

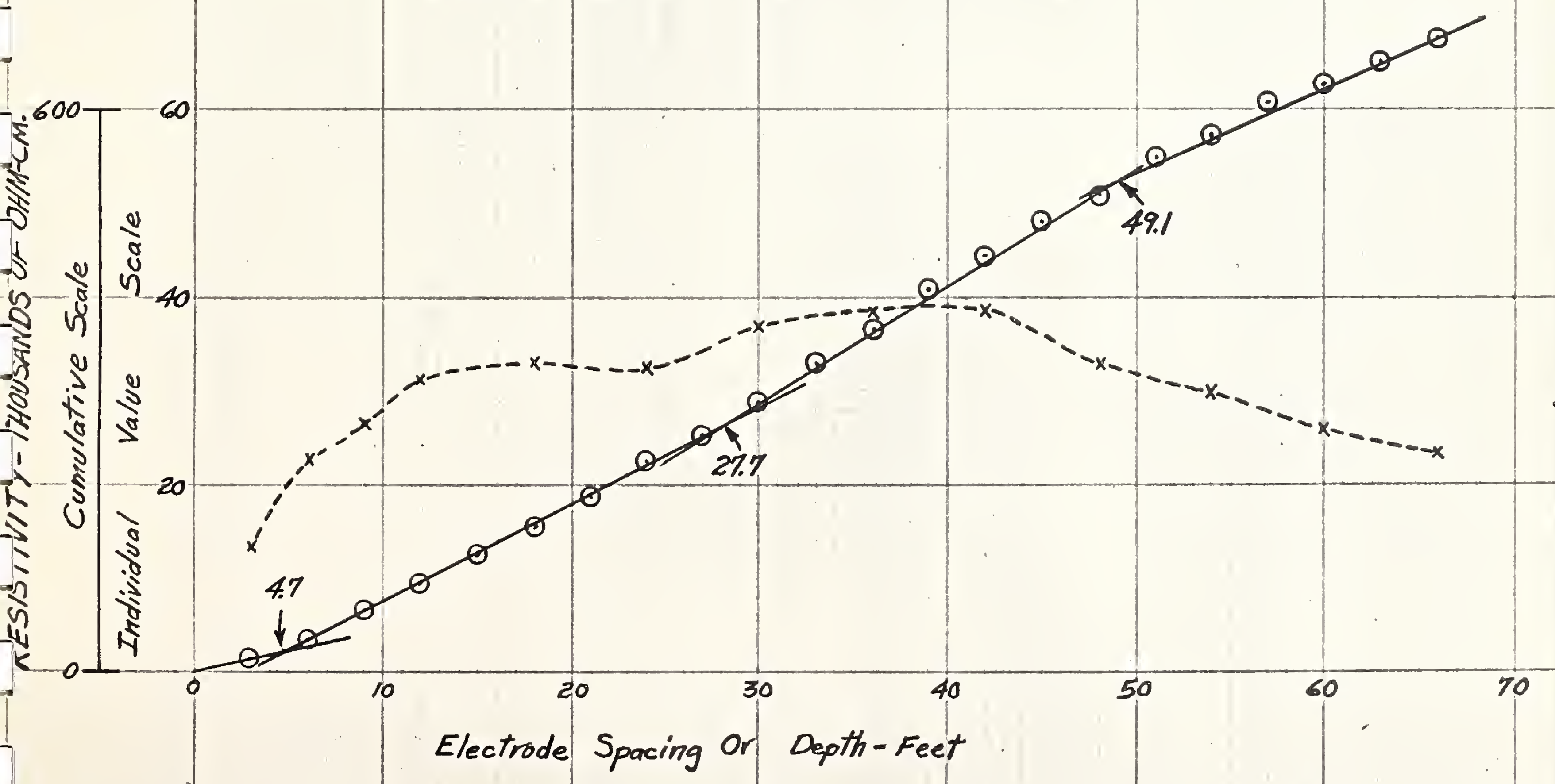
LANDSLIDE RESEARCH PROJECT
LIVINGSTON LANDSLIDE
November 2, 1966

Resistivity Test No. 1 @ Hole A-3



LANDSLIDE RESEARCH PROJECT
LIVINGSTON LANDSLIDE
November 3, 1966

Resistivity Test No. 2 @ Hole A-1



CONTROL LINE A ESTABLISHED 7/29/66

Record of Movement

Station and	Date of Measurement													
Original Elev.	8/12/66	8/22/66	8/30/66	9/8/66	9/22/66	11/2/66	12/19/66	3/2/67						
0+00	--	--	--	--	--	--	--	.17Rt.						
4576.58	--	--	--	--	--	--	4576.58	4576.60						
0+50	--	--	--	--	--	--	--	.23Rt.						
4577.91	--	--	--	--	--	--	4577.93	4577.93						
1+00	--	--	.01Rt.	.01Rt.	--	--	--	.23Rt.						
4579.59	--	--	--	--	--	--	4579.60	4579.59						
1+33.79	.01Rt.	--	.01Rt.	.01Rt.	--	--	.01Rt.	.23Rt.						
4581.17	--	--	--	--	--	--	4581.18	4581.19						
1+50	.02Rt.	.02Rt.	.02Rt.	.02Rt.	.02Rt.	.02Rt.	.02Rt.	.23Rt.						
4581.58	--	--	--	--	--	--	4581.15	4581.59						
2+00	.02Rt.	--	--	--	--	--	.04Rt.	.20Rt.						
4581.96	--	--	--	--	--	--	4581.95	4581.95						
2+50	--	--	--	--	.03Rt.	.03Rt.	.02Rt.	.17Rt.						
4582.02	--	--	--	--	--	--	4582.01	4582.00						
3+00	--	--	.02Lt.	.03Lt.	.04Lt	.07Lt.	.05Lt.	.03Rt.						
4581.94	--	--	--	--	--	--	4581.93	4581.92						
3+50	--	.01Lt	.04Lt.	.04Lt.	.05Lt.	.09Lt.	.06Lt.	--						
4581.86	--	--	--	--	--	--	4581.84	4581.82						
4+00	--	.01Lt.	.04Lt.	.04Lt.	.05Lt.	.08Lt.	.06Lt.	.01Rt.						
4581.74	--	--	--	--	--	--	4581.72	4581.70						
4+50	--	.02Lt.	.02Lt.	.04Lt.	.06Lt	.10Lt.	.06Lt.	--						
4581.62	--	--	--	--	--	--	4581.61	4581.59						
5+00	--	.02Lt.	.03Lt.	.04Lt	.06Lt.	.10Lt.	.05Lt.	--						
4581.13	--	--	--	--	--	--	4581.12	4581.11						
5+50	--	--	.03Lt.	.03Lt.	.05Lt.	.07Lt.	.02Lt.	--						
4580.35	--	--	--	--	--	--	4580.34	4580.33						

CONTROL LINE A ESTABLISHED 7/29/66

Record of Movement

Station and	Date of Measurement							
Original Elev.	8/12/66	8/22/66	8/30/66	9/8/66	9/22/66	11/2/66	12/19/66	3/2/67
6+00	--	--	.03Lt.	.03Lt.	.03Lt	.06Lt	.01Lt.	.02Rt.
4579.31	--	--	--	--	--	--	4579.31	4579.30
6+50	--	--	--	--	--	--	.06Rt.	.11Rt
4578.20	--	--	--	--	--	--	4578.25	4578.25
7+00	--	--	--	--	--	--	.09Rt.	.12Rt.
4576.70	--	--	--	--	--	--	4576.72	4576.72
7+50	.04Rt.	.04Rt.	.04Rt.	.04Rt.	.04Rt.	.06Rt.	.14Rt.	.17Rt.
4574.82	--	--	--	--	--	--	4574.86	4574.86
8+00	--	.03Rt.	.03Rt.	.03Rt.	.03Rt.	.05Rt.	.12Rt.	.15Rt.
4572.73	--	--	--	--	--	--	4572.76	4572.76
8+50	--	--	--	--	--	--	.05Rt.	.08Rt.
4570.66	--	--	--	--	--	--	4570.71	4570.71
9+00	--	--	--	--	--	--	.05Rt.	.11Rt.
4569.12	--	--	--	--	--	--	4569.12	4569.25
9+50	--	--	.02Rt.	.02Rt.	.02Rt.	.02Rt.	.02Rt.	.17Rt.
4567.65	--	--	--	--	--	--	--	4567.75

Land de arc roj HPR 5)
Livingston Landslide

CONTROL LINE B ESTABLISHED 8/2/66

Record of Movement

Station and	Date of Measurement												
Original Elev.	8/15/66	8/22/66	8/30/66	9/8/66	9/22/66	11/2/66	12/19/66	2/16/67					
0+00	--	--	--	--	--	--	.02Rt.	.04Rt.					
4645.58	--	--	--	--	--	--	--	4645.57					
0+50	--	--	--	--	--	.04Rt.	.09Rt.	.10Rt.					
4641.77	--	--	--	--	--	--	--	4641.75					
1+00	--	--	--	--	--	.02Rt.	.05Rt.	.09Rt.					
4638.01	--	--	--	--	4637.99	--	4637.99	4637.97					
1+50	.01Rt.	--	--	--	--	.04Rt.	.09Rt.	.09Rt.					
4635.63	--	--	--	--	4635.61	--	4635.60	4635.59					
2+00	--	--	--	--	--	.05Rt.	.10Rt.	.10Rt.					
4634.62	--	--	--	--	4634.60	--	4634.60	4634.58					
2+50	--	--	--	--	--	.09Rt.	.10Rt.	.13Rt.					
4633.23	--	--	--	--	4633.22	--	4633.23	4633.22					
3+00	.04Rt.	.06Rt.	.07Rt.	.08Rt.	.18Rt.	.69Rt.	1.08Rt.	1.38Rt.					
4633.14	--	--	--	--	4633.08	--	4632.90	4632.81					
3+50	.04Rt.	.07Rt.	.09Rt.	.09Rt.	.22Rt.	.70Rt.	1.16Rt.	1.53Rt.					
4632.75	--	--	--	--	4632.70	--	4632.51	4632.42					
4+00	.03Rt.	.10Rt.	.10Rt.	.10Rt.	.21 Rt.	.71 Rt.	1.16Rt.	1.50Rt.					
4630.40	--	--	--	--	4630.34	--	4630.17	4630.09					
4+50	.05Rt.	.09Rt.	.09Rt.	.09Rt.	.20Rt.	.69Rt.	1.10Rt.	1.42Rt.					
4628.89	--	--	--	--	4628.83	--	4628.67	4628.59					
5+00	.04Rt.	.09Rt.	.09Rt.	.09Rt.	.18Rt.	.57Rt.	.97Rt.	1.28Rt.					
4635.16	--	--	--	--	4635.11	--	4634.94	4634.85					
5+50	.01 Rt.	--	--	--	--	--	--	--					
4634.71	--	--	--	--	4634.70	--	4634.70	4634.69					
6+00	--	--	--	--	--	--	--	--					
4650.16	--	--	--	--	4650.15	--	4650.16	4650.14					

CONTROL LINE B ESTABLISHED 8/2/66

Record of Movement

Station and	Date of Measurement							
Original Elev.	8/15/66	8/22/66	8/30/66	9/8/66	9/22/66	11/2/66	12/19/66	2/16/67
6+50	--	--	--	--	--	--	--	--
4658.44	--	--	--	--	--	--	--	4658.42
7+00	--	--	--	--	--	--	--	--
4660.62	--	--	--	--	4660.62	--	4660.64	4660.59
7+50	--	--	--	--	--	--	--	--
4661.78	--	--	--	--	--	--	4661.79	4661.73
8+00	--	--	--	--	--	--	--	--
4663.21	--	--	--	--	--	--	--	--
8+50	--	--	--	--	--	--	--	--
4663.39	--	--	--	--	--	--	--	--
9+00	--	--	--	--	--	--	--	--
4664.31	--	--	--	--	--	--	--	--
9+50	--	--	--	--	--	--	--	--
4665.39	--	--	--	--	--	--	--	--
10+00	--	--	--	--	--	--	--	--
4665.28	--	--	--	--	--	--	--	--

CONTROL LINE C ESTABLISHED 8/3/66

Record of Movement

Station and Original Elev.	Date of Measurement												
	8/15/66	8/22/66	8/30/66	9/8/66	9/22/66	11/2/66	12/19/66	2/16/67					
0+00	--	--	--	--	--	--	--	--					
4581.16	--	--	--	--	--	--	--	4581.19					
0+50	--	--	--	--	--	--	--	.10Rt.					
4581.88	--	--	--	--	--	--	--	4581.89					
1+00	--	--	.01Rt.	--	--	--	.02Rt.	.07Rt.					
4596.89	--	--	--	--	--	--	--	4596.87					
1+50	--	--	--	--	--	--	.01Rt.	.07Rt.					
4614.95	--	--	--	--	--	--	--	4614.92					
2+00	.01Lt.	--	--	--	--	--	--	.08Rt.					
4630.03	--	--	--	--	--	--	--	4629.99					
2+14.66	--	--	.02Rt.	.02Rt.	.02Rt.	.02Rt.	.02Rt.	.02Rt.					
4634.62	--	--	--	--	--	--	--	4634.58					
2+50	--	--	--	.01Rt.	.02Rt.	--	.03Rt.	.03Rt.					
4645.73	--	--	--	--	4645.70	--	--	4645.70					
3+00	--	--	--	.02Rt.	.02Rt.	--	.05Rt.	.05Rt.					
4660.82	--	--	--	--	4660.78	--	4660.81	4660.75					
3+50	--	.09Rt.	.03Rt.	.03Rt.	.04Rt.	.12Rt.	.24Rt.	.24Rt.					
4674.67	--	--	--	--	4674.63	--	4674.55	4674.49					
4+00	--	.09Rt.	.09Rt.	.10Rt.	.15Rt.	.42Rt.	.78Rt.	1.01Rt.					
4685.43	--	--	--	--	4685.33	--	4685.06	4684.91					
4+50	--	.04Rt	.10Rt.	.11Rt.	.18Rt.	.48Rt.	.82Rt.	1.07Rt.					
4697.06	--	--	--	--	4696.96	--	4696.67	4696.49					
5+00	--	.03Rt.	.05Rt.	.10Rt.	.17Rt.	.51Rt.	.85Rt.	1.06Rt.					
4702.82	--	--	--	--	4702.75	--	4702.59	4702.47					
5+50	--	.03Rt.	.07Rt.	.09Rt.	.13Rt.	.40Rt.	.68Rt.	.89Rt.					
4704.45	--	--	--	--	4704.28	--	4703.91	4703.65					

CONTROL LINE C ESTABLISHED 8/3/66

Record of Movement

Station and	Date of Measurement												
Original Elev.	8/15/66	8/22/66	8/30/66	9/8/66	9/22/66	11/2/66	12/19/66	2/16/67					
6+00	--	.03Rt.	.05Rt.	.07Rt.	.07Rt.	.36Rt.	.66Rt.	.86Rt.					
4722.55	--	--	--	--	4722.44	--	4722.09	4721.84					
6+50	--	--	.01Rt.	.02Rt.	.02Rt.	.10Rt.	.03Rt.	.03Rt.					
4743.98	--	--	--	--	4643.94	--	4643.91	4643.83					
7+00	--	--	--	--	--	.01Rt.	--	--					
4776.96	--	--	--	--	4776.93	--	4776.91	4776.97					
7+50	--	--	--	--	--	--	--	--					
4796.99	--	--	--	--	--	--	4796.98	4796.98					
8+00	--	--	--	--	--	--	--	--					
No Reading							--	4798.35					
8+50	--	--	--	--	--	--	--	--					
4809.53	--	--	--	--	--	--	4809.52	4809.52					
9+00	--	--	--	--	--	--	--	--					
4816.06	--	--	--	--	--	--	--	--					
9+50	--	--	--	--	--	--	--	--					
4835.57	--	--	--	--	--	--	--	--					
10+00	--	--	--	--	--	--	--	--					
4853.09	--	--	--	--	--	--	--	--					
10+50	--	--	--	--	--	--	--	--					
4875.81	--	--	--	--	--	--	--	--					
11+00	--	--	--	--	--	--	--	--					
4893.78	--	--	--	--	--	--	--	--					

CONTROL LINE D ESTABLISHED 8/8/66

Record of Movement

Station and Original Elev.	Date of Measurement			
	8/22/66	9/22/66	12/19/66	2/24/67 3/2/67
0+00	--	--	--	--
4567.69	--	--	4567.69	4567.72
0+50	--	--	--	--
4568.38	--	--	4568.37	4568.40
1+00	--	--	.10Rt.	--
4568.90	--	--	4568.92	4568.96
1+50	--	--	.10Rt.	.04Rt.
4568.95	--	--	4568.96	4569.01
2+00	--	--	?	?
4569.07	--	--	4569.08	--
2+50	--	--	.09Rt.	.04Rt.
4568.50	--	--	4568.51	4568.54
3+00	--	--	.09Rt.	.02Rt.
4568.18	--	--	4568.20	4568.24
3+50	--	--	.08Rt.	.04Rt.
4567.52	--	--	4567.54	4567.58
4+00	--	.04Rt.	.07Rt.	03.Rt.
4567.08	--	--	4567.10	4567.14
4+50	--	.02Rt.	.08Rt.	--
4567.14	--	--	4567.17	4567.22
5+00	--	--	.03Rt.	.04Rt.
4566.71	--	--	4566.71	4566.73
5+50	--	--	--	.09Lt.
4566.90	--	--	4566.89	4566.91
6+00	--	--	--	.17Lt.
4566.06	--	--	4566.06	4566.08

CONTROL LINE D ESTABLISHED 8/8/66

Record of Movement

Station and Original Elev.	Date of Measurement 8/22/66	9/22/66	12/19/66	2/24/67
6+50	--	--	--	.15Lt.
4570.23	--	--	4570.22	4570.24
7+00	--	--	--	.23Lt.
4576.55	--	--	--	4576.55
7+50	--	--	--	.17Lt.
4576.75	--	--	--	4576.76
8+0	--	--	--	.18Lt.
4577.46	--	--	--	4577.47
8+50	--	--	--	Hit by Snow Plow
4578.53	--	--	--	--
11+50	--	--	--	.18Rt.
4576.29	--	--	--	4576.28
12+00	--	--	--	.10Rt.
4579.75	--	--	--	4579.71
12+50	--	--	--	.05Rt.
4580.31	--	--	--	4580.28
13+00	--	--	--	.03Rt.
4578.11	--	--	--	4578.09

CONTROL LINE E ESTABLISHED 10/14/66

Record of Movement

Station and	Date of Measurement													
Original Elev.	11/2/66	12/19/66	2/16/67											
0+00	--	--	--											
4808.53	--	--	--											
0+50	--	--	--											
4800.46	--	--	--											
1+00	--	--	--											
4792.11	--	--	--											
1+50	--	--	--											
4787.33	--	--	--											
2+00	--	--	--											
4789.45	--	--	--											
2+50	--	--	--											
4784.27	--	--	--											
3+00	--	--	--											
4779.00	--	--	--											
3+50	--	--	--											
4774.28	--	--	--											
4+00	--	--	--											
4768.84	--	--	--											
4+50	--	--	--											
4771.36	--	--	--											
5+00	--	--	--											
4778.21	--	--	--											
5+50	--	--	--											
4781.93	--	--	--											
6+00	--	--	--											
4782.78	--	--	--											

CONTROL LINE E ESTABLISHED 10/14/66

Record of Movement

Station and Original Elev.	Date of Measurement		
	11/2/66	12/19/66	2/16/67 3/2/67*
6+50	--	--	--
4800.36	--	--	--
7+00	--	--	--
4819.43	--	4819.43	4819.37*
7+50	--	--	--
4821.73	--	4821.73	4821.67*
8+00	.10Rt.	.50Rt.	.89Rt.
4819.10	--	4818.24	4817.57*
8+50	.12Rt.	35Rt.	.45Rt.
4818.50	--	4817.80	4817.25*
9+00	--	--	--
4812.35	--	4812.35	4812.36*
9+50	--	--	--
4806.67	--	--	4806.47*
10+00	--	--	--
4802.61	--	--	4802.41*

Livingston Landslide

CONTROL LINE H ESTABLISHED 1/12/67

Record of Movement

Station and	Date of Measurement													
Original Elev.	1/12/67	2/16/67												
0+00	--	--												
4580.09	--	--												
0+50	--	--												
4580.85	--	--												
1+00	--	--												
4580.65	--	--												
1+37.58	--	--												
4580.42	--	--												
1+50	--	--												
4580.26	--	--												
2+00	--	--												
4579.56	--	--												
2+50	--	--												
4577+70	--	--												
3+00	--	--												
4576.46	--	--												
4+05	--	--												
4575.90	--	--												
4+55	--	--												
4575.60	--	--												
5+05	--	--												
4575.73	--	--												
5+60	--	--												
4575.76	--	--												

ab. Form 30
Rev sed 11-22-55

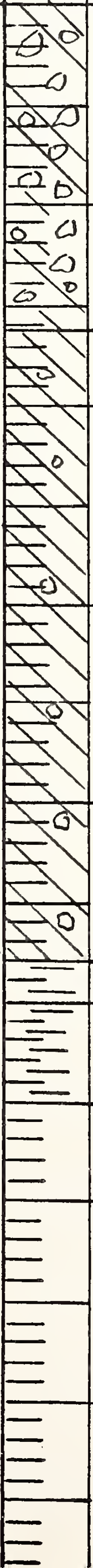
MONTANA HIGHWAY COMMISSION

Helena, Montana

Core Log No. 681
Project No. HPR-1(5)
Hole No. A-1
Termini Landslide Research Project
Date Taken Aug. 17, 18,19,22, 1966
Location 40' Lt. Temp. Line Sta. 1572+71.5
Structure Livingston Landslide
Party Chief Swanson
Others Deegan & Stevens

Miscellaneous Data	
Depth of Hole	55.0'
Rock	@ 48.0 '
Wt. of Hammer	140#
Average Fall of Hammer	30"
Elev. of Ground Water.	22.3'

Stratification: Elev.	Depth	Legend	Description of Materials Type, Color & Consistency
4580.2			Firm fractured limestone with tan clayey silt. A-4(1)
	16.2'		Soft tan clayey silt with limestone fragments. A-4(3)
	48.0'		Greenish gray shale
	55.0'		Bottom of Hole



Remarks

Total NX Casing

2" Sample Tube Penetration Test - 140# Hammer

Casing Blows	Penet-ration	Rotary Drilling	
50/R	0.4'	@	5.0' to 5.4'
50/R	0.4'	@	10.0' to 10.4'
22/27/6	1.5'	@	15.0' to 16.5'
36/12/13	1.5'	@	20.0' to 21.5'
6/8/8	1.5'	@	25.0' to 26.5'
12/8/7	1.5'	@	30.4' to 31.9'
27/13/23	1.5'	@	35.0' to 36.5'
19/16/15	1.5'	@	40.0' to 41.5'
19/22/32	1.5'	@	45.0' to 46.5'

Core Drilling Data

5.4	to	10.0	Core Recovery = 40%
10.4	to	15.0	" " = 40%
46.5	to	50.0	" " = 80%
50.0	to	55.0	" " = 40%

Used NX 5' Rigid barrel.

Thin walled shelby tubes

2" shelby from 26.5' to 28.0' in 4 sec.
2½" shelby from 30.0' to 30.4' in 3 sec.

Left 40' Perforated Casing in hole.

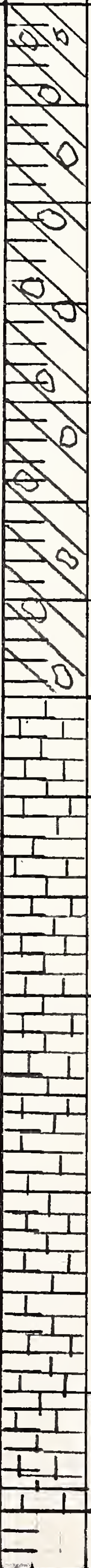
Water Levels

10/11/66	22.0'
10/17/66	22.9'
10/21/66	22.3'
11/1/66	22.2'
11/29/66	22.2'
12/23/66	22.3'

b. Form 30
Revised 11-22-55

MONTANA HIGHWAY COMMISSION
Helena, Montana

Core Log No. 682
Project No. HPR -1(5) Hole No. A-2
Termini Landslide Research Project
Date Taken Aug. 23, 24, 25, 26, 1966
Location Temp. Line 34' Lt. Sta. 1576+18
Structure Livingston Landslide
Party Chief Swanson
Others Deegan & Stevens



Stratification			Description of Materials Type, Color & Consistency
Elev.	Depth	Legend	
4579.1			A-4(4) Limestone cobbles and Boulders - all fragmented in matrix of soft tan silty clay. Very dense below 16.0'.
	35.0		Dull gray, mottled fine crystalline Limestone with thin $\frac{1}{4}$" to $\frac{1}{2}$" thick seams of brown plastic clay.
	76.0		Bottomed hole in same material.

Miscellaneous Data

Depth of Hole	76.0
Rock @ '	35.0
Wt. of Hammer	140#
Average Fall of Hammer	30"
Elev. of Ground Water.	26.2'

Remarks

Total N.X. Casing = 35.4

2" Sample Tube Penetration Test - 140# Hammer

Blows	Penetration	Rotary Drilling	
50/R	0.3	@	15.0' to 15.3'
50/R	0.3	@	20.0' to 20.3'
50/R	0.2	@	25.0' to 25.2'
50/R	0.2	@	30.0' to 30.2'

Core Drilling Data

30.2	to	32.3	Core Recovery = 75%
32.3	to	35.0	" " = 50%
35.0	to	40.0	" " = 40%
40.0	to	45.0	" " = 50%
45.0	to	50.0	" " = 75%
50.0	to	55.0	" " = 70%
55.0	to	65.0	" " = 100%
65.0	to	68.0	" " = 100%
68.0	to	76.0	" " = 100%

Used 5' Rigid core barrel to 45.0'
Used 10' Swivel core barrel to 76.0'

Used Carboloy Bit on NX Casing to 28.0'
Used Diamond Bit on NX Casing to 35.4'

Thin walled shelby tube sample.

$2\frac{1}{2}$" shelby tube 5.0' to 6.5' in 6 sec. (No sample)

2" shelby tube 6.5' to 7.6' in 3 sec. (poor sample)

Left 60' Perforated Casing in Hole.

Water Levels

10/11/66	27.4'
10/17/66	26.6'
10/21/66	26.7'
11/1/66	26.9'
11/29/66	27.2'
12/23/66	27.4'

b. Form 30
Revised 11-22-55

MONTANA HIGHWAY COMMISSION
Helena, Montana

Core Log No. 683 Project No. HPR -1 (5) Hole No. A-3
Termini Landslide Research Project Date Taken Sept. 1, to Oct. 6, 1966
Location 460' Lt. Temp. Line Sta. 1574+39 Structure Livingston Landslide
Party Chief Swanson Others Deegan & Stevens

Miscellaneous Data	
Depth of Hole	216.0'
Rock	
Wt. of Hammer	140#
Average Fall of Hammer	30"
Elev. of Ground Water.	162.8'

Stratification Elev.	Stratification Depth	Description of Materials Type, Color & Consistency
4714.9		Limestone rubble with Some Silt.
	2.5	Soft Clayey Silt with limestone fragments, mostly gravel sizes.
	20.7	Limestone fragments & greenish shale -firm-
	25.0	Greenish gray shale with a few, very thin soft layers.
	73.0	Very soft clay, possible slip zone.
	78.0	79.1 to 79.9 Hard red shale.

Remarks

Total NX Casing - 115'
Total BX Casing - 140.4'

2" Sample Tube Penetration Test - 140#

Blows	Penetration		Depth
8/6/4	1.5	@	5.0' to 6.5'
3/3/4	1.5	@	11.5' to 13.0'
4/4/5	1.5	@	15.0' to 16.5'
24/17/29	1.5	@	20.7' to 22.2'
50/R	0.4	@	78.0' to 78.4'

Core Drilling Data

From		To				
25.0	to	35.0	Core	Recovery	=	45%
35.0	to	41.7	"	"	=	50%
41.7	to	46.0	"	"	=	95%
46.0	to	50.5	"	"	=	100%
50.5	to	56.0	"	"	=	35%
56.0	to	66.0	"	"	=	23%
66.0	to	70.0	"	"	=	62%
70.0	to	73.5	"	"	=	90%
73.5	to	78.0	"	"	=	98%
78.4	to	83.5	"	"	=	80%
83.5	to	91.0	"	"	=	8%
91.0	to	96.0	"	"	=	80%
96.0	to	100.0	"	"	=	20%
100.0	to	103.8	"	"	=	10%
103.8	to	107.6	"	"	=	55%
107.6	to	111.6	"	"	=	50%
111.6	to	116.0	"	"	=	34%
116.0	to	119.0	"	"	=	17%
119.0	to	123.2	"	"	=	75%
123.2	to	127.6	"	"	=	67%
127.6	to	133.2	"	"	=	35%
133.2	to	134.4	"	"	=	50%
134.4	to	137.2	"	"	=	90%
137.2	to	147.3	"	"	=	81%
147.3	to	157.3	"	"	=	95%
157.3	to	167.0	"	"	=	100%
167.0	to	177.0	"	"	=	100%

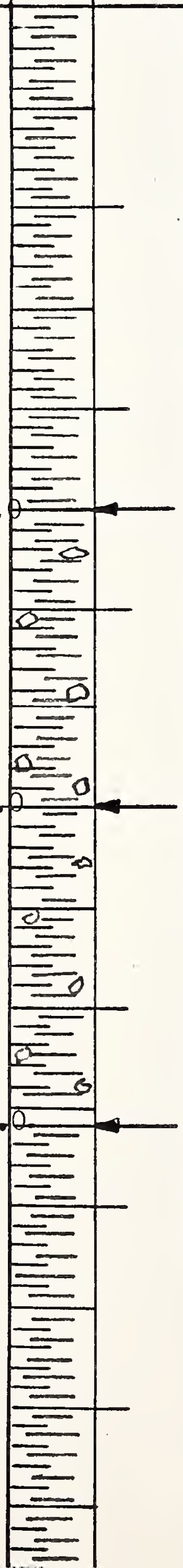
ab. Form 30
Revised 11-22-55

MONTANA HIGHWAY COMMISSION
Helena, Montana

Core Log No. 683 Project No. HPR-1 (5) Hole No. A-3
Termini Landslide Research Project Date Taken Sept. 1 to Oct. 1966
Location 460' Lt. Temp. Line Sta.1574+39 Structure Livingston Landslide
Party Chief Swanson Others Deegan & Stevens

Miscellaneous Data	
Depth of Hole	216.0'
Rock	
Wt. of Hammer	140#
Average Fall of Hammer	30"
Elev. of Ground Water	162.8'

Stratification Elev.	Stratification Depth	Description of Materials Type, Color & Consistency
		Greenish gray shale with a few, thin limestone beds.
	105.0	Greenish gray and maroon shale with limestone rubble - Produces water. (some thin sand layers)
	120.0	Greenish to purple shale with limestone fragments. Very Micaeous.
	136.0	Gray shale with thin beds of fragmental limestone.



Remarks

Core Drilling Data Continued.

177.0	to	187.0	Core Recovery = 100%
187.0	to	196.4	" " = 100%
196.4	to	206.0	" " = 100%
206.0	to	216.0	" " = 100%

Thin walled samples

2"	Shelby Tube @	6.5' to 8.0' in 4 sec.
2½"	" " @	10.0' to 11.5' in 4 sec.
2½"	" " @	20.0' to 20.7' in 3 sec.

Set 160' Perforated Casing in hole

Water Levels

10/17/66	162.8'
10/21/66	162.8'
10/27/66	162.8
10/31/66	162.8'
12/22/66	163.2'

@ 116' & 119' - Small artesian flows for 2 to 3 hours when penetrated. Evidently small pods, completely drained in 8 to 10 hours.

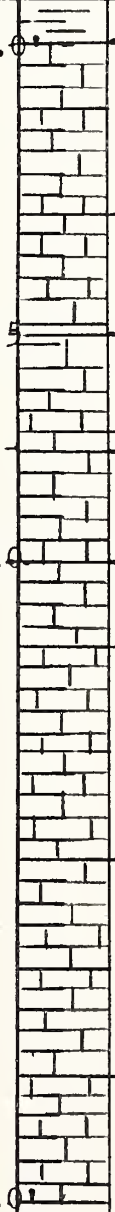
ıb. Form 30
Revised 11-22-55

MONTANA HIGHWAY COMMISSION
Helena, Montana

Core Log No. 683 & 32 Project No. HPR -1 (5) Hole No. A-3
Termini Landslide Research Project Date Taken Sept. 1 to Oct. 6, 1966
Location 460'Lt. Temp. Line Sta. 1574+39 Structure Livingston Landslide
Party Chief Cook Others Green and Yost

Miscellaneous Data	
Depth of Hole	216.0'
Rock	
Wt. of Hammer	140#
Average Fall of Hammer	30"
Elev. of Ground Water.	162.8'

Stratification: Elev.	Stratification: Depth	Stratification: Legend	Description of Materials Type, Color & Consistency	Casing: Blows	Casing: Penet-ration	Rotary Drilling	Remarks
	162.0'		Gray limestone with thin gray shale layers.				
	176.5		Gray & Brown mottled limestone.				
			Gray mottled limestone.				
	186.0		Gray & Brown mottled limestone very fractured at 190' ± 2' (some pyrite in the limestone) Bottomed hole in gray & brown mottled limestone.				
	216.0'						



ab. Form 30
Revised 11-22-55

MONTANA HIGHWAY COMMISSION
Helena, Montana

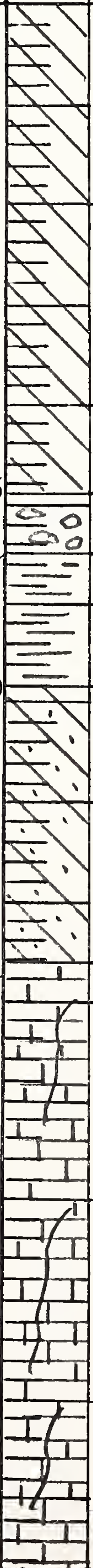
Core Log No. 33 Project No. HPR -1(5) Hole No. A-4
Termini Landslide Research Project Date Taken Oct. 6 to Nov. 10, 1966
Location 685'SW of Hole A-3 Structure Livingston Landslide
Party Chief Cook Others Green & Yost

Miscellaneous Data	
Depth of Hole	365.4'
Rock	Limestone & Shale
Wt. of Hammer	140# & 300#
Average Fall of Hammer	30"
Elev. of Ground Water.	241.5'

Stratification

Elev.	*Depth*	*Description of Materials Type, Color & Consistency*
4800.2		Stiff Brown Clayey Silt.
	24.5	Dense Brown Silty M/C Limestone Gravel.
	27.4	Soft Gray-Green Shale W/Siltstone lenses.
	34.0	Dense Brown-Red-Buff Silty Sandy M/C Limestone Gravel w/occ. boulder.
	48.1	Hard Buff-Red Limestone, extensively fractured, brecciated in part, interbedded silty & shaly lenses.

Legend



Remarks

2" Sample Tube Penetration Test - 140# Hammer

Casing Blows	*Penetration*	*Rotary Drilling*	*Remarks*	
6/20/19	1.5	@	24.5 to 26.0	
11/15/18	1.5	@	30.1 to 31.6	
22/R	0.8	@	36.3 to 37.1	
13/15/19	1.5	@	40.3 to 41.8	
20/26/20	1.5	@	45.0 to 46.5	
50/R	0.2	@	50.3 to 50.5	
50/R	0.0	@	55.3 to 55.3	No Penetration
11/32/47	1.5	@	90.8 to 92.3	
11/50/R	0.9	@	95.0 to 95.9	
27/50/R	0.9	@	165.7 to 166.6	
16/14/31	1.5	@	254.0 to 255.5	

BX Casing Drive 300# Hammer

Blows	*Penetration*	*Rotary Drilling*	*Remarks*
50	0.9	@	1.0 to 1.9
24	1.0	@	6.0 to 7.0
16	1.0	@	11.0 to 12.0
11	1.0	@	16.0 to 17.0
18	1.0	@	21.0 to 22.0

2½" Shelby Tube Samples

8.0'	to	9.4'	18 Sec.
12.6'	to	14.1'	13 "
14.1'	to	15.6'	11 "
17.7'	to	19.2"	12 "
22.7'	Refusal		
165.0'	to	165.7'	

Started to Core 55.6'

Drew	59.8'	57%	Rec.
"	66.0	37%	"
"	70.0	75%	"
"	75.0	50%	"
"	80.0	74%	"
"	90.0	50%	"

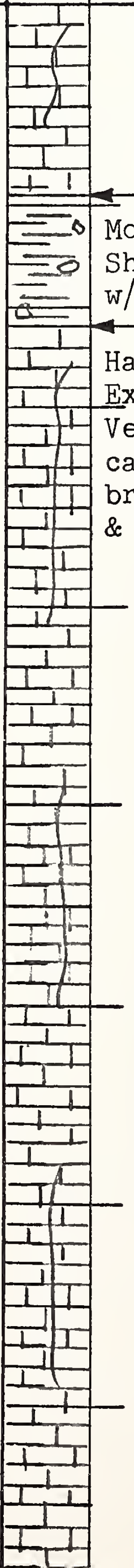
Started to Core 95.9'

Drew	100	16%	"
"	110.0	60%	"
"	120.0	40%	"
"	130.0	36%	"
"	135.0	50%	"

ab. Form 30
Revised 11-22-55

MONTANA HIGHWAY COMMISSION
Helena, Montana

Core Log No. 33 Project No. HPR-1(5) Hole No. A-4
Termini Landslide Research Project Date Taken Oct. 6 to Nov. 10, 1966
Location 685' SW of Hole A-3 Structure Livingston Landslide
Party Chief Cook Others Green & Yost



Stratification: Elev.	Depth	Legend	Description of Materials Type, Color & Consistency	Casing: Blows	Casing: Penet-ration	Rotary Drilling
	80.0		Refer to sheet # 1			
	89.5		(Possible Slip Zone) Moderately Soft Green-Gray Shale & Buff Clayey Silt w/Hard Limestone fragments.			
	96.0		Hard Gray-Buff Limestone, Extensive high angle & Vertical iron Stained & calcite covered fractures, brecciated in part with red & buff silt.			

Miscellaneous Data

Depth of Hole	365.4'
Rock	Limestone & Shale
Wt. of Hammer	140# & 300#
Average Fall of Hammer	30"
Elev. of Ground Water.	241.5'

Remarks

Drew	140.0	76% Rec.
"	145.0	50% "
"	150.0	100% "
"	155.0	33% "
"	160.0	25% "
"	165.0	50% "
"	170.0	100% "
"	175.0	80% "
"	178.0	100% "
"	184.0	85% "
"	190.0	40% "
"	195.0	80% "
"	200.0	25% "
"	205.0	40% "
"	210.0	40% "
"	215.0	25% "
"	220.0	25% "
"	225.0	25% "
"	230.0	10% "
"	235.0	10% "
"	238.0	20% "
"	239.3	50% "
"	245.5	13% "
"	247.0	None
"	253.0	80% "
"	254.0	100% "
"	257.8	30% "
"	263.6	15% "
"	267.4	42% "
"	268.1	80% "

Started to Core 269.4'

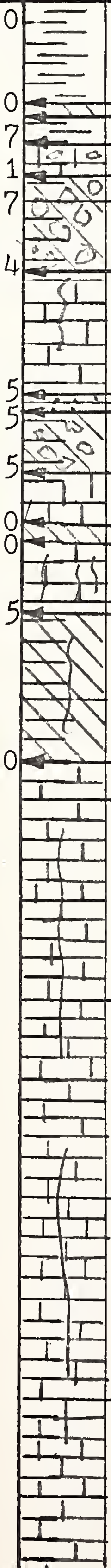
Drew	276.6	80% Rec.
"	281.7	80% "
"	286.7	100% "
"	296.7	96% "
"	299.6	100% "
"	309.6	100% "
"	316.1	100% "
"	322.4	100% "
"	326.4	100% "
"	331.7	100% "
"	335.0	100% "

Lab. Form 30
Revised 11-22-55

MONTANA HIGHWAY COMMISSION
Helena, Montana

Core Log No. 33 Project No. HPR-1(5) Hole No. A-4
Termini Landslide Research Project Date Taken Oct. 6 to Nov. 10, 1966
Location 685' SW of Hole A-3 Structure Livingston Landslide
Party Chief Cook Others Green & Yost

Miscellaneous Data	
Depth of Hole	365.4'
Rock	Limestone & Shale
Wt. of Hammer	140# & 300#
Average Fall of Hammer	30"
Elev. of Ground Water.	241.5'



Elev.	Depth	Description of Materials Type, Color & Consistency	Blows	Penet-ration	Rotary Drilling
	160.0	(Possible Slip Zones between 160.0' & 198.0') Soft Mottled Green-Buff-Brown Clayey Silt w/Hard Limestone fragments.			
	165.0	Hard Ls.& Clayey Silt Breccia.			
	165.7	Soft mottled Brown-Red-Buff Clayey Silt w/Hard Ls. fragments.			
	167.1	Hard Gray-Red Vugular Ls.			
	168.7	Hard Red-Buff Ls.&Silt Breccia w/soft Yellow-Brown Clayey Silt.			
	173.4	Hard Gray-Green Ls. w/red vug. holes & vertical fractures.			
	179.5	Hard Gray F/M Sandstone.			
	180.5	Hard Gray Ls. & Buff-Brown Clayey Silt Breccia.			
	183.5	Hard Gray-Red Vugular Ls.			
	186.0	Soft Buff Clayey Silt, Slickensided.			
	187.0	Hard Gray-Brown Ls., Extensive fractures.			
	190.5	M. Hard Mottled Buff-Red Calcareous Siltstone, clayey & brecciated in part.			
	198.0	Hard Gray-Brown Limestone, extensive iron stained vertical & high angle fractures, occasional Gray-Green Siltstone lenses.			

Remarks

Drew	339.2	100% Rec.
"	341.7	100% "
"	351.3	100% "
"	352.3	100% "
"	358.6	100% "
"	365.4	100% "

No water return to 257.8' except for small zones.

Total NX Casing 238.4'

Total BX Casing 268.4'

Left 275' Perforated Conduit in hole.

Water Levels

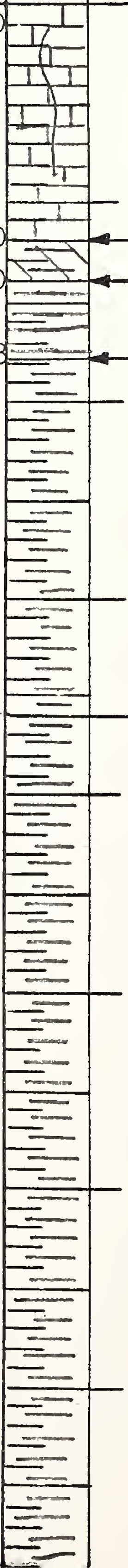
11/14/66	241.0'
11/15/66	241.0'
11/29/66	241.5'
12/22/66	241.8'

Lab. Form 30
Revised 11-22-55

MONTANA HIGHWAY COMMISSION
Helena, Montana

Core Log No. 33 Project No. HPR-1(5) Hole No. A-4
Termini Landslide Research Project Date Taken Oct. 6 to Nov. 10, 1966
Location 685' SW of Hole A-3 Structure Livingston Landslide
Party Chief Cook Others Green & Yost

Miscellaneous Data	
Depth of Hole	365.4'
Rock	Limestone & Shale
Wt. of Hammer	140# & 300#
Average Fall of Hammer	30"
Elev. of Ground Water	241.5'



Stratification: Elev.	Stratification: Depth	Stratification: Legend	Description of Materials Type, Color & Consistency	Casing: Blows	Casing: Penet-ration	Rotary Drilling	Remarks
	240.0		Refer to previous sheet				
			(Possible Slip Zone 252.0-257.8')				
	252.0		Soft Buff-Green Clayey Silt & Hard Brown Ls. & Green Shale Breccia.				
	254.0		Soft Dark Green-Black Shale & Clay w/hard Buff Ls. fragments & thin lenses				
	257.8						Full water returns below 257.8'
			Interbedded M. Hard Dark Gray-Green Shale & Hard Gray Limestone, brecciated in part, occasional slickensides, bedding varies from near horizontal to vertical.				
			Vertical Bedding.				

Lab. Form 30
Revised 11-22-55

MONTANA HIGHWAY COMMISSION
Helena, Montana

Core Log No. 33 Project No. HPR-1(5) Hole No. A-4
Termini Landslide Research Project Date Taken Oct. 6 to Nov. 10, 1966
Location 685' SW of Hole A-3 Structure Livingston Landslide
Party Chief Cook Others Green & Yost

Miscellaneous Data	
Depth of Hole	365.4'
Rock	Limestone & Shale
Wt. of Hammer	140# & 300 #
Average Fall of Hammer	30"
Elev. of Ground Water.	241.5'

Stratification			Description of Materials Type, Color & Consistency	Casing		Rotary Drilling	Remarks
Elev.	Depth	Legend		Blows	Penet-ration		
	320.0						
			Vertical Bedding				
			Interbedded M. Hard Dark Gray-Green Shale & Hard Gray Limestone, brecciated in part, occasional slickensides, bedding varies from near horizontal to vertical.				
			Soft Clayey Zone.				
			Vertical Bedding.				
	365.4		Bottom of Hole.				

STATE HIGHWAY COMMISSION OF MONTANA

Helena, Montana

Dist. Lab No.

Lab No. 332941 Sample No. Hole A-1 Project No. HPR-1(5)

Termini Landslide Research Project - Livingston Landslide

Date sampled 8/17-22/66 Date received 8/22/66 Kind of Deposit Landslide

Submitted by Clark Title Geologist III Address Helena

Quantity Pit by stationing 40' Lt. Temp. Line Sta. 1572+71.5

Pit is in

Represented by Lab No. County

Owner of Pit Address

Mile or stationing represented by prepared sample

Examined for Moisture, Hydrometer, Atterburg Limits, Unconfined Test.

Wt. of sample taken Lbs. 100%

Wt. retained 4-Mesh Lbs. %

Wt. passing 4-Mesh Lbs. %

Before wash After wash LBW

Fines % Total sample %

GRAVEL — Depth 1.0'-3.0'

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	4½"		
	4"		
	3½"		
	3"		
	2½"		
	2"		
	1½"		
	1¼"		100
	1"		99
	5/8" ¾"		97
	½"		94
	⅜"		92
	4M		84

Depth 1.0'-3.0' SAND Hydrometer

~~Ind. Wt. Ret.~~ Pct. Pass.	Size	~~Tot. Wt. Pass.~~ Depth 16.5'-28.0'	Pct.
	⅜"		
	4M		
71	10M		100
61	20M		80
57	30M		
54	40M		69
51	50M		
49	60M		62
46	80M		
46	~~100M~~	140M	53
40.5	200M		51
40.5	~~270M~~	.005mm	16
	~~325M~~	.003mm	11

Wear % Wt. SG

* LL PL PI

Permeability Capillary rise

Maximum density Optimum moisture

** Soil Classification

Coarse Portion is % crushed

Dust Ratio —4+10 —4+40

Absorption Color

Volume Swell Results Material Oiled With

% by Weight of

Swell: 24 hr. %; 8 day %. Condition of Specimen:

Acceptable for use with oil

AASHO Swell and Strip Test:

Nat. % Strip F. C. Asp. %

Mfg. % Strip F. C. Asp. %

Remarks:

Depth	Natural Moisture
25.5'-26.0'	10.7%
26.5'-28.0'	9.9%
49.0'	18.5%

	LL	PL	PI
* Depth 1.0' - 3.0'	17.00	14.89	2.11
Depth 26.5' - 28.0'	23.00	19.51	3.49

** Depth 1.0' - 3.0' = A-4(1)

Depth 26.5' - 28.0' = A-4(3)

Unconfined Compression Test @ 26.5'

Shear strength = 1/2 Qu = 1033 #/ft.^{2}

FORM NO. 123—REV. 54

7

STATE HIGHWAY COMMISSION OF MONTANA

Helena, Montana

Dist. Lab No.

Lab No. 334879 Sample No. Hole A-3, Depth 6.5'-8.0' Project No. HPR-1(5)

Termini Landslide Research Project - Livingston Landslide

Date sampled 8/30/66 Date received 9/2/66 Kind of Deposit Landslide

Submitted by Clark Title Geologist III Address Helena

Quantity Pit by stationing 460' Lt. Temp. Line Sta. 1574+39

Pit is in

Represented by Lab No. County

Owner of Pit Address

Mile or stationing represented by prepared sample

Examined for Moisture, Density, Atterburg Limits, Gradation, Unconfined

Wt. of sample taken Lbs. 100%

Wt. retained 4-Mesh Lbs. %

Wt. passing 4-Mesh Lbs. %

Before wash After wash LBW

Fines % Total sample %

GRAVEL

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	4½"		
	4"		
	3½"		
	3"		
	2½"		
	2"		
	1½"		
	1¼"		
	1"		
	⅝" ¾"		
	½"		70.4
	⅜"		75.1
	4M		68.6

SAND

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	⅜"		
	4M		
	10M		57.3
	20M		
	30M		
	40M		28.5
	50M		
	60M		
	80M		
	100M		
	200M		10.9
	270M		
	—270M		

Wear % Wt. SG

LL 33.16 PL 29.45 PI 3.71

Permeability Capillary rise

Maximum density Optimum moisture

Soil Classification A-1-b

Coarse Portion is % crushed

Dust Ratio —4+10 —4+40

Absorption Color

Volume Swell Results Material Oiled With

% by Weight of

Swell: 24 hr. %; 8 day %. Condition of Specimen:

Acceptable for use with oil

AASHO Swell and Strip Test:

Nat. % Strip F. C. Asp. %

Mfg. % Strip F. C. Asp. %

Remarks:

Natural Wet Density = 134 #/ft.^{3}

" Dry " = 114 "

" Moisture Content = 17.6%

Unconfined Compression Test

Qu = 3657 #/ft.^{2}

Shear strength = 1/2 Qu = 1828 lbs./ft.^{2}

FORM No. 123—REV. 54

7

STATE HIGHWAY COMMISSION
OF MONTANA
Helena, Montana

Dist. Lab No.

Lab No. 336670 Sample No. Hole A-3, Depth 111.0' Project No. HPR-1(5)
Termini Landslide Research Project - Livingston Landslide
Date sampled 9/9/66 Date received 10/4/66 Kind of Deposit Landslide
Submitted by Clark Title Geologist III Address Helena
Quantity Pit by stationing 460' Lt. Temp. Line Sta. 1574+39
Pit is in
Represented by Lab No. County
Owner of Pit Address
Mile or stationing represented by prepared sample
Examined for Hydrometer & Atterberg Limits

Wt. of sample taken Lbs. 100%
Wt. retained 4-Mesh Lbs. %
Wt. passing 4-Mesh Lbs. %
Before wash After wash LBW
Fines % Total sample %

GRAVEL

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	4½"		
	4"		
	3½"		
	3"		
	2½"		
	2"		
	1½"		
	1¼"		
	1"		
	⅝" ¾"		
	½"		
	⅜"		
	4M		

SAND

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	⅜"		
	4M		
	10M		100
	20M		80
	30M		
	40M		68
	50M		
	60M		61
	80M		
	~~XXXX~~	140M	50
	200M		46
	~~XXXXXX~~	..005mm	14
	~~XXXXXX~~	.003mm	10

Wear % Wt. SG
LL 26.64 PL 24.35 PI 2.29
Permeability Capillary rise
Maximum density Optimum moisture
Soil Classification A-4(2)
Coarse Portion is % crushed
Dust Ratio —4+10 —4+40
Absorption Color
Volume Swell Results Material Oiled With
% by Weight of
Swell: 24 hr. %; 8 day %. Condition of Specimen:

Acceptable for use with oil
AASHO Swell and Strip Test:
Nat. % Strip F. C. Asp. %
Mfg. % Strip F. C. Asp. %

Remarks:

FORM NO. 123—REV. 54

STATE HIGHWAY COMMISSION OF MONTANA

Helena, Montana

Dist. Lab No.

Lab No. 334880 Sample No. Hole A-3, Depth 10.0' - 11.5' Project No. HPR-1(5)

Termini Landslide Research Project - Livingston Landslide

Date sampled 8/30/66 Date received 9/2/66 Kind of Deposit Landslide

Submitted by Clark Title Geologist III Address Helena

Quantity Pit by stationing 460' Lt. Temp. Line Sta. 1574+39

Pit is in

Represented by Lab No. County

Owner of Pit Address

Mile or stationing represented by prepared sample

Examined for Moisture, Density, Atterburg Limits, Gradation.

Wt. of sample taken Lbs. 100%

Wt. retained 4-Mesh Lbs. %

Wt. passing 4-Mesh Lbs. %

Before wash After wash LBW

Fines % Total sample %

GRAVEL

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	4½"		
	4"		
	3½"		
	3"		
	2½"		
	2"		
	1½"		
	1¼"		
	1"		
	⅝" ¾"		
	½"		80.9
	⅜"		74.7
	4M		61.0

SAND

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	⅜"		
	4M		
	10M		44.0
	20M		
	30M		
	40M		19.0
	50M		
	60M		
	80M		
	100M		
	200M		6.7
	270M		
	—270M		

Wear % Wt. SG

LL 33.75 PL 28.14 PI 5.61

Permeability Capillary rise

Maximum density Optimum moisture

Soil Classification A-1 A-1-a

Coarse Portion is % crushed

Dust Ratio —4+10 —4+40

Absorption Color

Volume Swell Results Material Oiled With

% by Weight of

Swell: 24 hr. %; 8 day %. Condition of Specimen:

Acceptable for use with oil

AASHO Swell and Strip Test:

Nat. % Strip F. C. Asp. %

Mfg. % Strip F. C. Asp. %

Remarks:

Natural Wet Density = 139 #/ft.^{3}

" Dry " = 112 "

" Moisture Content = 24.6%

FORM NO. 123—REV. 54

STATE HIGHWAY COMMISSION
OF MONTANA
Helena, Montana

Dist. Lab No.

Lab No. 337838 Sample No. Hole A-3, Depth 12'-20' Project No. HPR -1(5)

Termini Landslide Research Project - Livingston Landslide

Date sampled 10/10/66 Date received 10/17/66 Kind of Deposit Landslide

Submitted by Clark Title Geologist III Address Helena

Quantity Pit by stationing 460' Lt. Temp. Line Sta. 1574+39

Pit is in

Represented by Lab No. County

Owner of Pit Address

Mile or stationing represented by prepared sample

Examined for Hydrometer, Atterburg Limits, Moisture, Density.

Wt. of sample taken Lbs. 100%

Wt. retained 4-Mesh Lbs. %

Wt. passing 4-Mesh Lbs. %

Before wash After wash LBW

Fines % Total sample %

	GRAVEL		
Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	4½"		
	4"		
	3½"		
	3"		
	2½"		
	2"		
	1½"		
	1¼"		
	1"		
	⅝" ¾"		
	½"		
	⅜"		
	4M		

	SAND		Hydrometer
Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	⅜"		
	4M		
	10M		100
	20M		95
	30M		
	40M		92
	50M		
	60M		90
	80M		
	~~100M~~	140M	77
	200M		63
	~~270M~~	.005mm	5
	~~270M~~	.001mm	1

Wear % Wt. SG

LL NP PL NP PI NP

Permeability Capillary rise

Maximum density Optimum moisture

Soil Classification A-4(6)

Coarse Portion is % crushed

Dust Ratio —4+10 —4+40

Absorption Color

Volume Swell Results Material Oiled With

% by Weight of

Swell: 24 hr. %; 8 day %. Condition of Specimen:

Acceptable for use with oil

AASHO Swell and Strip Test:

Nat. % Strip F. C. Asp. %

Mfg. % Strip F. C. Asp. %

Remarks:

Natural Moisture Content = 7.7%

Natural Density = 105 #/ft.^{3}

FORM NO. 123—REV. 54

STATE HIGHWAY COMMISSION
OF MONTANA
Helena, Montana

Dist. Lab No.

Lab No. 338457 Sample No. Hole A-4, Surface to 162.3' Project No. HPR-1(5)
Termini Landslide Research Project - Livingston Landslide
Date sampled 10/18/66 Date received 10/27/66 Kind of Deposit PossibleSlip Zone
Submitted by Kraft Title Geologist II Address Helena
Quantity Pit by stationing 685' SW Hole A-3
Pit is in
Represented by Lab No. County
Owner of Pit Address
Mile or stationing represented by prepared sample
Examined for Hydrometer, Atterberg Limits, Moisture

Wt. of sample taken Lbs. 100%
Wt. retained 4-Mesh Lbs. %
Wt. passing 4-Mesh Lbs. %
Before wash After wash LBW
Fines % Total sample %

GRAVEL

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	4½"		
	4"		
	3½"		
	3"		
	2½"		
	2"		
	1½"		
	1¼"		
	1"		
	⅝" ¾"		
	½"		
	⅜"		
	4M		

SAND Hydrometer

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
@ Depth	⅜"	of 162.0' to	162.3'
	4M		
	10M		100
	20M		98
	30M		
	40M		96
	50M		
	60M		95
	80M		
	~~100M~~	140M	93
	200M		92
	~~270M~~	.005mm	64
	~~270M~~	.001mm	26

Wear % Wt. SG
LL 32.75 PL 27.06 PI 5.69
Permeability Capillary rise
Maximum density Optimum moisture
Soil Classification A-4(8)
Coarse Portion is % crushed
Dust Ratio −4+10 −4+40
Absorption Color
Volume Swell Results Material Oiled With
% by Weight of
Swell: 24 hr. %; 8 day %. Condition of Specimen:

Acceptable for use with oil
AASHO Swell and Strip Test:
Nat. % Strip F. C. Asp. %
Mfg. % Strip F. C. Asp. %

Remarks:

Natural Moisture Content = 23.7% @ 162.0' to 162.3'

Direct Shear Tests

Depth of 12.6' to 14.1', Saturated Sample - C = 500 Lbs/ft.^{2}
$\phi = 10^\circ$

Depth of 12.6' to 14.1', Natural Moisture - C = 220 Lbs/ft.^{2}
$\phi = 20^\circ$

Depth of 17.7' to 18.9' Natural Moisture - C = 430 Lbs/ft.^{2}
$\phi = 19^\circ$

FORM NO. 123—REV. 54

STATE HIGHWAY COMMISSION
OF MONTANA
Helena, Montana

Dist. Lab No.

Lab No. 338458 Sample No. Hole A-4, Depth 165.0' - 165.7' Project No. HPR-1(5)
Termini Landslide Research Project - Livingstone Landslide
Date sampled 10/18/66 Date received 10/27/66 Kind of Deposit Possible Slip Zone
Submitted by P. Kraft Title Geologist II Address Helena
Quantity Pit by stationing 685' SW Hole A-3
Pit is in
Represented by Lab No. County
Owner of Pit Address
Mile or stationing represented by prepared sample
Examined for Gradation, Atterberg Limits, Moisture, Density, Unconfined Test.

Wt. of sample taken Lbs. 100%
Wt. retained 4-Mesh Lbs. %
Wt. passing 4-Mesh Lbs. %
Before wash After wash LBW
Fines % Total sample %

GRAVEL

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	4½"		
	4"		
	3½"		
	3"		
	2½"		
	2"		
	1½"		
	1¼"		100
	1"		75
	⅝" ¾"		64
	½"		
	⅜"		46
	4M		33

SAND

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	⅜"		
	4M		
	10M		24
	20M		
	30M		
	40M		17
	50M		
	60M		15
	80M		
	100M		
	200M		11.0
	270M		
	—270M		

Wear % Wt. SG
LL NP PL NP PI NP
Permeability Capillary rise
Maximum density Optimum moisture
Soil Classification A-1-a
Coarse Portion is % crushed
Dust Ratio —4+10 —4+40
Absorption Color
Volume Swell Results Material Oiled With
% by Weight of
Swell: 24 hr %; 8 day %. Condition of Specimen:

Acceptable for use with oil
AASHO Swell and Strip Test:
Nat. % Strip F. C. Asp. %
Mfg. % Strip F. C. Asp. %

Remarks:

Natural Moisture Content = 8.2%

Natural Density = $124^{\#}/\text{ft.}^3$

Unconfined Compression Test

$Qu = 100^{\#}/\text{ft.}^3$

Shear strength $= \frac{Qu}{2} = 50$ Lbs/ft.^{2}

FORM NO. 123—REV. 54

STATE HIGHWAY COMMISSION OF MONTANA

Helena, Montana

Dist. Lab No.

Lab No. 338459 Sample No. Hole A-4, Depth 165.7'-166.6' Project No. HPR-1(5)

Termini Landslide Research Project - Livingston Landslide

Date sampled 10/18/66 Date received 10/27/66 Kind of Deposit Possible Slip Zone

Submitted by Kraft Title Geologist II Address Helena

Quantity Pit by stationing 685' SW Hole A-3

Pit is in

Represented by Lab No. County

Owner of Pit Address

Mile or stationing represented by prepared sample

Examined for Moisture Content

Wt. of sample taken Lbs. 100%

Wt. retained 4-Mesh Lbs. %

Wt. passing 4-Mesh Lbs. %

Before wash After wash LBW

Fines % Total sample %

GRAVEL

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	4½"		
	4"		
	3½"		
	3"		
	2½"		
	2"		
	1½"		
	1¼"		
	1"		
	⅝" ¾"		
	½"		
	⅜"		
	4M		

SAND

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	⅜"		
	4M		
	10M		
	20M		
	30M		
	40M		
	50M		
	60M		
	80M		
	100M		
	200M		
	270M		
	—270M		

Wear % Wt. SG

LL PL PI

Permeability Capilary rise

Maximum density Optimum moisture

Soil Classification

Coarse Portion is % crushed

Dust Ratio —4+10 —4+40

Absorption Color

Volume Swell Results Material Oiled With

% by Weight of

Swell: 24 hr. %; 8 day %. Condition of Specimen:

Acceptable for use with oil

AASHO Swell and Strip Test:

Nat. % Strip F. C. Asp. %

Mfg. % Strip F. C. Asp. %

Remarks:

Natural Moisture Content = 19.9%

FORM NO. 123—REV. 54

STATE HIGHWAY COMMISSION
OF MONTANA
Helena, Montana

Dist. Lab No.

Lab No. 338460 Sample No. Hole A-4, Depth 164.0'-164.8' Project No. HPR - 1(5)
Termini Landslide Research Project - Livingston Landslide
Date sampled 10/18/66 Date received 10/27/66 Kind of Deposit Possible Slip Zone
Submitted by Kraft Title Geologist II Address Helena
Quantity Pit by stationing 685' SW Hole A-3
Pit is in
Represented by Lab No. County
Owner of Pit Address
Mile or stationing represented by prepared sample
Examined for Moisture, Unconfined Test

Wt. of sample taken Lbs. 100%
Wt. retained 4-Mesh Lbs. %
Wt. passing 4-Mesh Lbs. %
Before wash After wash LBW
Fines % Total sample %

GRAVEL

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	4½"		
	4"		
	3½"		
	3"		
	2½"		
	2"		
	1½"		
	1¼"		
	1"		
	⅝" ¾"		
	½"		
	⅜"		
	4M		

SAND

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	⅜"		
	4M		
	10M		
	20M		
	30M		
	40M		
	50M		
	60M		
	80M		
	100M		
	200M		
	270M		
	—270M		

Wear % Wt. SG
LL PL PI
Permeability Capillary rise
Maximum density Optimum moisture
Soil Classification A-4(8)
Coarse Portion is % crushed
Dust Ratio —4+10 —4+40
Absorption Color
Volume Swell Results Material Oiled With
% by Weight of
Swell: 24 hr. %; 8 day %. Condition of Specimen:

Acceptable for use with oil
AASHO Swell and Strip Test:
Nat. % Strip F. C. Asp. %
Mfg. % Strip F. C. Asp. %

Remarks:

Natural Moisture Content = 20.7%

Unconfined Compression Test

Qu = 9230 #/ft.^{2}

Shear Strength = 1/2 Qu = 4615 lbs/ft.^{2}

FORM NO. 123—REV. 54

STATE HIGHWAY COMMISSION
OF MONTANA
Helena, Montana

Dist. Lab No.

Lab No. 338461 Sample No. Hole A-4 Depth 166.8'-167.6' Project No. HPR-1(5)
Termini Landslide Research Project - Livingston Landslide
Date sampled 10/18/66 Date received 10/27/66 Kind of Deposit Possible Slip Zone
Submitted by Kraft Title Geologist II Address Helena
Quantity Pit by stationing 685' SW Hole A-3
Pit is in
Represented by Lab No. County
Owner of Pit Address
Mile or stationing represented by prepared sample
Examined for Atterberg Limits, Unconfined Test

Wt. of sample taken Lbs. 100%
Wt. retained 4-Mesh Lbs. %
Wt. passing 4-Mesh Lbs. %
Before wash After wash LBW
Fines % Total sample %

GRAVEL

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	4½"		
	4"		
	3½"		
	3"		
	2½"		
	2"		
	1½"		
	1¼"		
	1"		
	⅝" ¾"		
	½"		
	⅜"		
	4M		

SAND

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	⅝"		
	4M		
	10M		
	20M		
	30M		
	40M		
	50M		
	60M		
	80M		
	100M		
	200M		
	270M		
	—270M		

Wear % Wt. SG
LL 33.00 PL 24.03 PI 8.97
Permeability Capillary rise
Maximum density Optimum moisture
Soil Classification A-4(8)
Coarse Portion Is % crushed
Dust Ratio —4+10 —4+40
Absorption Color
Volume Swell Results Material Oiled With
% by Weight of
Swell: 24 hr. %; 8 day %. Condition of Specimen:

Acceptable for use with oil
AASHO Swell and Strip Test:
Nat. % Strip F. C. Asp. %
Mfg. % Strip F. C. Asp. %

Remarks:

Unconfined Compression Test

Average Qu (2 Tests) = 9600 $^{\#}/\text{ft.}^2$

Shear strength = $\frac{Qu}{2}$ = 4800 lbs/ft.^{2}

Form No. 123—Rev. 54

STATE HIGHWAY COMMISSION
OF MONTANA
Helena, Montana

Dist. Lab No.

Lab No. 334981 Sample No. Surface Sample Project No. HPR -1(5)
Termini Landslide Research Project - Livingston Landslide
Date sampled 8/24/66 Date received 9/2/66 Kind of Deposit Landslide
Submitted by Clark Title Geologist III Address Helena
Quantity Pit by stationing 41.5' Lt. Temp Line Sta. 1576+18
Pit is in
Represented by Lab No. County
Owner of Pit Address
Mile or stationing represented by prepared sample
Examined for Grading, Atterberg Limits.

Wt. of sample taken Lbs. 100%
Wt. retained 4-Mesh Lbs. %
Wt. passing 4-Mesh Lbs. %
Before wash After wash LBW
Fines % Total sample %

GRAVEL

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	4½"		
	4"		
	3½"		
	3"		
	2½"		
	2"		
	1½"		100
	1¼"		97
	1"		95
	⅝" ¾"		92
	½"		87
	⅜"		82
	4M		68

SAND

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	⅜"		
	4M		
	10M		53
	20M		41
	30M		37
	40M		34
	50M		31
	60M		29
	80M		26
	100M		25
	200M		19.6
	270M		19
Trace	−270M		

Wear % Wt. SG
LL PL PI NP
Permeability Capillary rise
Maximum density Optimum moisture
Soil Classification A-1-b
Coarse Portion is % crushed
Dust Ratio −4+10 −4+40
Absorption Color
Volume Swell Results Material Oiled With
% by Weight of
Swell: 24 hr. %; 8 day %. Condition of Specimen:

Acceptable for use with oil
AASHO Swell and Strip Test:
Nat. % Strip F. C. Asp. %
Mfg. % Strip F. C. Asp. %

Remarks:

FORM No. 123—REV. 54

STATE HIGHWAY COMMISSION OF MONTANA
Helena, Montana

Dist. Lab No.

Lab No. 334982 Sample No. Hole A-2 Project No. HPR-1(5)

Termini Landslide Research Project - Livingston Landslide

Date sampled 8/23-26/66 Date received 9/2/66 Kind of Deposit Landslide

Submitted by Clark Title Geologist III Address Helena

Quantity Pit by stationing 34' Lt. Temp. Line Sta. 1576+18

Pit is in

Represented by Lab No. County

Owner of Pit Address

Mile or stationing represented by prepared sample

Examined for Moisture, Hydrometer, Atterburg Limits, Unconfined Test.

Wt. of sample taken Lbs. 100%

Wt. retained 4-Mesh Lbs. %

Wt. passing 4-Mesh Lbs. %

Before wash After wash LBW

Fines % Total sample %

GRAVEL

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	4½"		
	4"		
	3½"		
	3"		
	2½"		
	2"		
	1½"		
	1¼"		
	1"		
	⅝" ¾"		
	½"		
	⅜"		
	4M		

SAND Hydrometer

Ind. Wt. Ret.	Size	Tot. Wt. Pass.	Pct.
	⅜"	Depth 6.5' -	7.5'
	4M		
	10M		100
	20M		99
	30M		
	40M		98
	50M		
	60M		96
	80M		
	~~100M~~	140M	67
	200M		53
	270M	.006mm	6
	~~270M~~	.003mm	4

Wear % Wt. SG

LL NP PL NP PI NP

Permeability Capillary rise

Maximum density Optimum moisture

Soil Classification Depth 6.5' - 7.5' A-4(4)

Coarse Portion is % crushed

Dust Ratio —4+10 —4+40

Absorption Color

Volume Swell Results Material Oiled With

% by Weight of

Swell: 24 hr. %; 8 day %. Condition of Specimen:

Acceptable for use with oil

AASHO Swell and Strip Test:

Nat. % Strip F. C. Asp. %

Mfg. % Strip F. C. Asp. %

Remarks:

Depth	Natural Moisture
1.0'	11.3%
6.5'-7.0'	13.7%
7.0'-7.5'	21.7%

Unconfined Compression Test @ 6.5'

Qu [illegible]

Shear strength = 1/2 Qu = 589#/ft.^{2}

LAB. FORM NO. 45
REV'D 5-56

STATE HIGHWAY COMMISSION OF MONTANA

Helena, Montana

FORM TO ACCOMPANY MISCELLANEOUS SAMPLES SENT FROM FIELD

Helena Lab. No. 338453 Project No. H.P.R. - 1(5)

Designation of Project Landslide Research Project

Date Sample Rec'd Field No.

Name of Material Limestone, Gray, Cryptöcyrstalline

Grade or Type Trade Name

Manufacturer of Material

Jobber or Dealer Directly Supplying Material

Quantity of Material Sample Represents

If this is a check or resample, please indicate

Name of Sampler C.H. Clark Title Geologist III

Address Helena Date of Sampling

Use this FORM ONLY when other Forms are not already provided.

Remarks Limestone sample from Drill Hole No. A-2, Depth 61 feet, Livingston Landslide.

Chemical Analysis

	*Standard	338453
Insoluble	6.66%	4.54%
Fe_2O_3	0.64%	0.64%
Ca O	48.79%	51.10%
Al_2O_3	0.015 %	0.86%
Mg O	1.87%	1.51%

* Standard from Test Hole A-3, 197.5' & 215.0' (average of 2)

LAB. FORM NO. 45
REV'D 5-56

STATE HIGHWAY COMMISSION OF MONTANA

Helena, Montana

FORM TO ACCOMPANY MISCELLANEOUS SAMPLES SENT FROM FIELD

Helena Lab. No.: 338454 Project No. H.P.R. -1 (5)

Designation of Project Landslide Research Project

Date Sample Rec'd Field No.

Name of Material Limestone, Brown, Fine Crystalline

Grade or Type Trade Name

Manufacturer of Material

Jobber or Dealer Directly Supplying Material

Quantity of Material Sample Represents

If this is a check or resample, please indicate

Name of Sampler C. H. Clark Title Geologist III

Address Date of Sampling

Use this FORM ONLY when other Forms are not already provided.

Remarks Limestone sample from Drill Hole No. A-2, Depth 61 feet, Livingston Landslide

Chemical Analysis

	* Standard	338453
Insoluble	30.54%	29.21%
Fe_2O_3	3.95%	3.22%
Ca O	19.87%	25.44%
Al_2O_3	0.53%	9.96%
Mg O	9.08%	9.52%

* Standard from Test Hole A-3, 197.5' & 215.0' (average of 2).

LAB. FORM NO. 45
REV'D 5-56

STATE HIGHWAY COMMISSION OF MONTANA

Helena, Montana

FORM TO ACCOMPANY MISCELLANEOUS SAMPLES SENT FROM FIELD

Helena Lab. No. 338455 Project No. H.P.R. - 1(5)

Designation of Project Landslide Research Project

Date Sample Rec'd Field No.

Name of Material Limestone, Gray, Cryptochrystalline

Grade or Type Trade Name

Manufacturer of Material

Jobber or Dealer Directly Supplying Material

Quantity of Material Sample Represents

If this is a check or resample, please indicate

Name of Sampler C.H. Clark Title Geologist III

Address Date of Sampling

Use this FORM ONLY when other Forms are not already provided.

Remarks Limestone sample from Drill Hole No. A-2, Depth 76 ft., Livingston Landslide.

Chemical Analysis

	*Standard	338455
Insoluble	6.66%	6.39%
Fe_2O_3	0.64%	0.52%
Ca O	48.79%	50.08%
Al_2O_3	0.015%	1.28%
Mg O	1.87%	1.69%

* Standard from Test Hole A-3, 197.5' & 215.0' (average of 2).

LAB. FORM NO. 45
REV'D 5-56

STATE HIGHWAY COMMISSION OF MONTANA

Helena, Montana

FORM TO ACCOMPANY MISCELLANEOUS SAMPLES SENT FROM FIELD

Helena Lab. No. 338456 Project No. H.P.R. - 1(5)

Designation of Project Landslide Research Project

Date Sample Rec'd Field No.

Name of Material Limestone, brown, fine crystalline

Grade or Type Trade Name

Manufacturer of Material

Jobber or Dealer Directly Supplying Material

Quantity of Material Sample Represents

If this is a check or resample, please indicate

Name of Sampler C. H. Clark Title Geologist III

Address Date of Sampling

Use this FORM ONLY when other Forms are not already provided.

Remarks Limestone sample from Drill Hole No. A-2, Depth 76 feet, Livingston Landslide.

Chemical Analysis

	*Standard	338456
Insoluble	30.54%	34.40%
Fe_2O_3	3.95%	3.33%
Ca O	19.87%	22.26%
Al_2O_3	0.53%	9.85%
Mg O	9.08%	9.45%

* Standard from Test Hole A-3, 197.5' & 215.0' (average of 2).

. Form 30
ised 11-22-55

MONTANA HIGHWAY COMMISSION
Helena, Montana

Core Log No. 491 Project No. F-217(11) Hole No. 1
Termini Livingston Date Taken February 5, 8, 1965
Location 171' Rt. Sta. 1576+15 Structure Landslide
Party Chief Swanson Others Horacek, Stevens

Miscellaneous Data
Depth of Hole 45.0 ft.
Rock
Wt. of Hammer 140#
Average Fall of Hammer 30"
Elev. of Ground Water. none

Remarks

Total 7" augers - 45.5 ft.

ratification Depth	Description of Materials Type, Color & Consistency
	Tan limestone fragments & clay.
9.0	Tan silty decomposed limestone.
11.5	Tan limestone fragments with thin clay lenses.
15.0	Tan limestone fragments.
22.5	Soft tan limestone fragments.
25.0	Tan limestone fragments.
30.0	Wet tan limestone fragments.
34.0	Greenish tan clay with some limestone fragments.
36.5	Grey green shale.
38.6	Limestone fragments.
45.0	Bottomed hole in fractured limestone.
	Two boxes core.

Standard 2" Penetration Test - 140# Hammer

Casing Blows	Casing Penet-ration	Rotary Drilling	Remarks
9/11/ 8	1.5	@	5.0 to 6.5'
13/24/15	1.5	@	10.0 to 11.5
6/ 8/10	1.5	@	15.0 to 16.5
27/41/48	1.5	@	20.0 to 21.5
18/19/39	1.5	@	25.0 to 26.5
43/50/ R	1.0	@	30.0 to 31.0
3/ 8/15	1.5	@	35.0 to 36.5
34/50/ R	0.6	@	40.0 to 40.6
25/ R	0.0	@	45.0'

Elevation set by Livingston Survey crew.

Lab. Form 30
Revised 11-22-55

Helena, Montana

Page 1 of 2 pages.

Core Log No. 492
Project No. F-217(11)
Hole No. 2
Termini Livingston
Date Taken February 8, 9, 16, 17, 18, 1965
Location 176' Lt. Sta. 1574+71
Structure Landslide
Party Chief Swanson
Others Horacek, Stevnns

Miscellaneous Data
Depth of Hole 100.0 ft.
Rock
Wt. of Hammer 140#
Average Fall of Hammer 30"
Elev. of Ground Water. none

Stratification			*Description of Materials Type, Color & Consistency*
Elev.	*Depth*	*Legend*	
17.1 ft.			Brown sandy silt & limestone fragments.
	12.6		Hard green clayey shale.
	17.0		Hard grey clayey shale.
	37.7		Hard grey limestone, fractured.
	48.0		Lost drill water
			Hard grey limestone, fractured.

Remarks

Total 7" Augers - 38.5 ft.

Total BX Casing - 38.6'ft.

Standard 2" Penetration Test - 140# Hammer

Blows	*Penetration*	*Rotary Drilling*	
4/ 4/ 5	1.5	@	5.0 to 6.5'
9/24/18	1.5	@	10.0 to 11.5
11/19/23	1.5	@	15.0 to 16.5
13/25/33	1.5	@	20.0 to 21.5
16/34/50	1.3	@	25.0 to 26.3
11/27/42	1.5	@	30.0 to 31.5
50/ R	0.2	@	35.0 to 35.2
25/ R	0.0	@	38.5'

Rotary Core Drilling Data - Started Core at 39.0 ft.

Draw	@	45.0'	Core Recovery	30%
Draw	@	49.0'	Core Recovery	20%
Draw	@	59.0'	Core Recovery	70%
Draw	@	69.0'	Core Recovery	28%
Draw	@	80.0'	Core Recovery	78%
Draw	@	90.0'	Core Recovery	65%
Draw	@	100.0'	Core Recovery	85%

Used rigid barrel with fine diamond impregnated bit.

Elevation set by Livingston Engineering crew.

Lab. Form 30
evised 11-22-55

MONTANA HIGHWAY COMMISSION
Helena, Montana

Page 2 of 2 pages.

Core Log No. 492
Project No. F-217(11)
Hole No. 2
Termini Livingston
Date Taken February 8, 9, 16, 17, 18, 1965
Location 176' Lt. Sta. 1574+71
Structure
Party Chief
Others

Stratification			*Description of Materials Type, Color & Consistency*	*Casing*		*Rotary Drilling*	*Miscellaneous Data* *Depth of Hole* *Rock* *Wt. of Hammer* *Average Fall of Hammer* *Elev. of Ground Water.* *Remarks*
Elev.	*Depth*	*Legend*		*Blows*	*Penet-ration*		
		▨	Hard grey fractured limestone.				
	100.0		← Bottomed hole in hard grey fractured limestone.				
			Five boxes core.				

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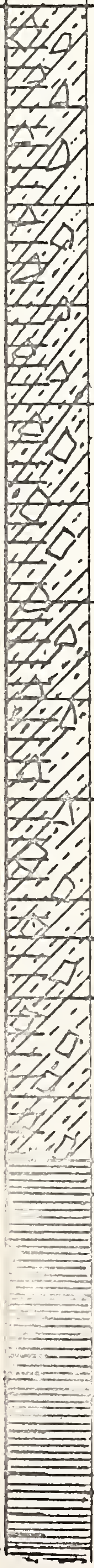
Core Log No. 493 Project No. F-217(11) Hole No. 3
Termini Livingston Date Taken February 9, 10, 11, 15, 1965
Location 170' Lt. Sta. 1573+00 Structure Landslide
Party Chief Swanson Others Horac Stevens

Miscellaneous Data	
Depth of Hole	80.0 ft.
Rock	
Wt. of Hammer	140# & 300#
Average Fall of Hammer	30"
Elev. of Ground Water	23.0 ft. Note



Stratification lev.	Stratification Depth	Description of Materials Type, Color & Consistency
19.1 ft.		Brown sandy silt & limestone fragments.
	47.0	Slightly damp brown sandy silt & limestone fragments.
	58.2	Hard green sandy shale.
	80.0	Bottomed hole in hard green sandy shale & limestone.

Remarks

Total 7" Augers - 53.0 ft.

Total BX Casing - 60.0 ft.

Standard 2" Penetration Test - 140# Hammer

Casing Blows	Casing Penetration	Rotary Drilling	
16/25/11	1.5	@	5.0 to 6.5'
8/13/18	1.5	@	10.0 to 11.5
8/15/16	1.5	@	15.0 to 16.5
12/25/32	1.5	@	20.0 to 21.5
12/21/25	1.5	@	25.0 to 26.5
19/38/50	1.4	@	30.0 to 31.4
13/15/27	1.5	@	35.0 to 36.5
13/18/17	1.5	@	40.0 to 41.5
9/14/50	1.4	@	45.0 to 46.4
11/14/11	1.5	@	50.0 to 51.5
25/ R	0.0	@	53.0'
31/32/14	1.5	@	55.0 to 56.5
15/27/37	1.5	@	60.0 to 61.5
22/50/ R	1.0	@	65.0 to 66.0 - No Recovery
50/ R	0.4	@	70.0 to 70.4

BX Casing Drive Count - 300# Hammer

23	1.0	@	57.0 to 58.0'
45	1.0	@	59.0 to 60.0

Rotary Core Drilling Data - Started Core at 70.4 ft.

Draw @ 80.0' Core Recovery 3%

NOTE: Ground water at 23.0', drill water.

NOTE: Drilled with Blue Demon bit from 61.5' to 70.0'.

Cored with rigid core barrel and fine diamond impregnated bit.

Two boxes core.

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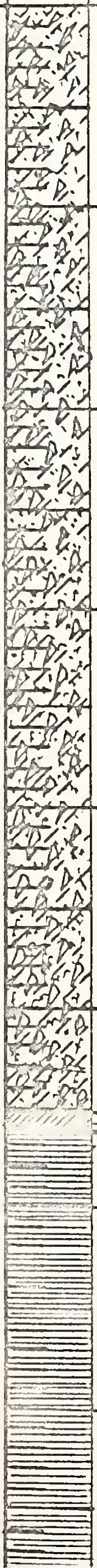
Core Log No. 494 Project No. F-217(11) Hole No. 4
Termini Livingston Date Taken February 18, 19, 23, 24, 25, 1965
Location 300' Lt. Sta. 1576+38 Structure Landslide
Party Chief Swanson Others Horacek, Stevens

Stratification Elev.	Depth	Legend	Description of Materials Type, Color & Consistency	Casing Blows	Penet-ration	Rotary Drilling	Miscellaneous Data Depth of Hole 101.3 ft. Rock Wt. of Hammer 140# & 300# Average Fall of Hammer 30" Elev. of Ground Water 50.1 ft. drill water Remarks
4 17			Stiff to hard brown sandy silt with limestone fragments.				Total BX Casing - 58.4 ft.
				2" Penetration Test - 140# Hammer			
				18/15/14	1.5	@	5.0 to 6.5'
				5/ 4/ 5	1.5	@	10.0 to 11.5
				19/20/23	1.5	@	15.0 to 16.5
				18/50/ R	0.8	@	20.0 to 20.8
				11/ 4/ 5	1.5	@	25.0 to 26.5
				9/10/15	1.5	@	30.0 to 31.5
				27/39/14	1.5	@	35.0 to 36.5
				9/ 9/ 7	1.5	@	40.0 to 41.5
				22/18/17	1.5	@	45.0 to 46.5
				10/17/16	1.5	@	50.0 to 51.5
				8/16/24	1.5	@	55.0 to 56.5
				14/32/44	1.5	@	60.0 to 61.5 - No Recovery
				17/27/47	1.5	@	65.0 to 66.5
				21/33/50	1.3	@	70.0 to 71.3
				26/50/ R	1.0	@	75.0 to 76.0
				44/50/ R	0.6	@	80.0 to 80.6
				25/50/ R	1.0	@	85.0 to 86.0
				37/50/ R	1.0	@	90.0 to 91.0
				25/34/50	1.4	@	95.0 to 96.4
				19/27/50	1.3	@	100.0 to 101.3
							NOTE: Drilled with Blue Demon bit from 56.5' to 100.0'
				BX Casing Drive Count - 300# Hammer			
	55.1		Soft grey-green Bentonitic clay, damp.	25	1.0	@	17.0 to 18.0'
	56.2			23	1.0	@	19.0 to 20.0
				29	1.0	@	22.0 to 23.0
			Hard grey-green sandy shale.	22	1.0	@	24.0 to 25.0
				15	1.0	@	27.0 to 28.0
				21	1.0	@	29.0 to 30.0
				12	1.0	@	32.0 to 33.0
				18	1.0	@	34.0 to 35.0
				13	1.0	@	37.0 to 38.0
				14	1.0	@	39.0 to 40.0
				27	1.0	@	42.0 to 43.0
				28	1.0	@	44.0 to 45.0
				23	1.0	@	47.0 to 48.0

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Core Log No. 494
Project No. F-217(11)
Hole No. 4
Termini
Date Taken
Location
Structure
Party Chief
Others

Stratification			Description of Materials Type, Color & Consistency	Casing		Rotary Drilling	Miscellaneous Data Depth of Hole Rock Wt. of Hammer Average Fall of Hammer Elev. of Ground Water
Elev.	Depth	Legend		Blows	Penet-ration		Remarks
	80.0		Hard grey-green sandy shale.				BX Casing Drive Count - 300# Hammer (cont.)
				23	1.0	@	49.0 to 50.0'
				26	1.0	@	52.0 to 53.0
				27	1.0	@	54.0 to 55.0
				Elevation set by Livingston Survey Crew			
	101.3		← Bottomed hole in hard grey-green sandy shale.				
			Possibility of limestone contact at 101.3 ft.				

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ore Log No. 495
Project No. F-217(11)
Hole No. 5
Termini Livingston
Date Taken February 26, March 1, 2, 4, 5, 8, 1965
Location 308' Lt. Sta. 1575+25
Structure S Landslide
Party Chief Swanson
Others Horacek, Stevens

Miscellaneous Data	
Depth of Hole	100.0 ft.
Rock	
Wt. of Hammer	140#
Average Fall of Hammer	30"
Elev. of Ground Water.	23.8' drill water

tratification: *El.* | *Depth* | *Legend*

Description of Materials Type, Color & Consistency

1.9

Depth	*Description of Materials*
	Brown sandy silt and limestone fragments.
20.0	Slightly damp.
29.0	Yellowish-tan silty and limestone fragments.
43.5	Hard grey-green sandy shale.

Remarks

Total BX Casing - 55.4 ft.

2" Standard Penetration Test - 140# Hammer

Casing *Blows*	*Penet-ration*	*Rotary Drilling*	*Remarks*
2/ 4/ 5	1.5	@	5.0 to 6.5'
6/ 9/ 7	1.5	@	10.0 to 11.5
5/ 8/ 8	1.5	@	15.0 to 16.5
9/12/18	1.5	@	20.0 to 21.5
14/19/17	1.5	@	25.0 to 26.5
9/10/15	1.5	@	30.0 to 31.5
7/11/13	1.5	@	35.0 to 36.5
10/10/19	1.5	@	40.0 to 41.5
17/30/39	1.5	@	45.0 to 46.5
33/42/50	1.4	@	50.0 to 51.4
28/23/50	1.3	@	55.0 to 56.3
22/50/ R	1.0	@	60.0 to 61.0
21/35/50	1.4	@	65.0 to 66.4
33/34/50	1.4	@	70.0 to 71.4
20/34/50	1.4	@	75.0 to 76.4
40/46.50	1.3	@	80.0 to 81.3
25/50/ R	0.9	@	85.0 to 85.9
30/50/ R	1.0	@	90.0 to 91.0
25/ R	0.0	@	95.0
25/ R	0.0	@	100.0

NOTE: Drilled to 55.0 ft. with 7" augers

Drilled with Blue Demon bit from 56.3' to 100.0'

Elevation set by Livingston Engineering crew.

Water elevation is trapped drill water.

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Core Log No. 495
Project No. F-217(11)
Hole No. 5
Termini
Date Taken
Location 308' Lt. Sta. 1575+25
Structure
Party Chief
Others

Miscellaneous Data
Depth of Hole 100.0 ft.
Rock
Wt. of Hammer
Average Fall of Hammer
Elev. of Ground Water.

Stratification			*Description of Materials Type, Color & Consistency*	*Casing*		*Rotary Drilling*	*Remarks*
Elev.	*Depth* 80.0	*Legend*		*Blows*	*Penet-ration*		
			Hard red clayey shale.				
	88.0		Hard grey-green sandy shale.				
	94.7		Very hard.				
	100.0		Bottomed hole in very hard grey-green sandy shale.				
			Three boxes core.				

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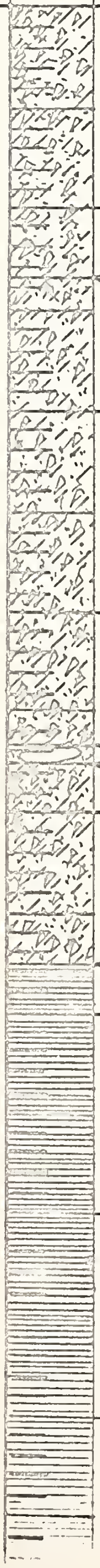
Core Log No. 496 Project No. F-217(11) Hole No. 6
Termini Livingston Date Taken March 8, 9, 10, 1965
Location 304' Lt. St. 1573+99 Structure Landslide
Party Chief Swanson Others Horacek , Stevens

Misc.	
Miscellaneous Data	
Depth of Hole	99.0 ft.
Rock	
Wt. of Hammer	140#
Average Fall of Hammer	30"
Elev. of Ground Water.	40.4 ft. **

Stratification

Elev. 694 ft.



Depth	*Description of Materials Type, Color & Consistency*
	Brown sandy silt and limestone fragments.
13.4	Slightly damp.
	Brown sandy silt and limestone fragments.
36.8	Limestone boulder (0.8')
37.6	Brown sandy silt and limestone fragments.
47.7	Hard grey-green sandy shale.

Remarks

Total BX Casing - 50.4 ft.

2" Standard Penetration Test - 140# Hammer

Casing Blows	*Casing Penet-ration*	*Rotary Drilling*	
13/16/12	1.5	@	4.0 to 5.5'
8/14/17	1.5	@	9.0 to 10.5
8/ 8/10	1.5	@	14.0 to 15.6
7/10/ 9	1.5	@	19.0 to 20.5
15/14/11	1.5	@	24.0 to 25.5
20/15/14	1.5	@	29.0 to 30.5
15/14/17	1.5	@	34.0 to 35.5
25/ R	0.0	@	37.1' No Penetration
19/11/17	1.5	@	44.0 to 45.5
25/38/37	1.5	@	49.0 to 50.5
34/31/33	1.5	@	54.0 to 55.5
21/29/46	1.5	@	59.0 to 60.5
24/37/47	1.5	@	64.0 to 65.5
18/50/ R	0.9	@	69.0 to 69.9
50/ R	0.4	@	74.0 to 74.4
25/50/ R	0.7	@	79.0 to 79.7
41/50/ R	0.7	@	84.0 to 84.7
40/50/ R	0.9	@	89.0 to 89.9
36/50/ R	0.7	@	94.0 to 94.7
25/ R	0.0	@	99.0'

Drilled with 7" augers to 37.1'

Drilled with Blue Demon bit from 50.5' to 99.0'

Elevation set by Livingston Engineering crew.

Water Elevation is trapped drill water.

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Core Log No. 496
Project No. F-217(11)
Hole No. 6
Termini
Date Taken
Location 304' Lt. Sta. 1573+99
Structure
Party Chief
Others

tratification			Description of Materials Type, Color & Consistency	Casing		Rotary Drilling	Miscellaneous Data
Elev.	Depth	Legend		Blows	Penet-ration		Depth of Hole 99.0 ft. Rock Wt. of Hammer Average Fall of Hammer Elev. of Ground Water.
	80.0		Hard grey-green sandy shale.				Remarks
	99.0		Bottomed hole in hard grey-green sandy shale.				
			Three boxes core.				

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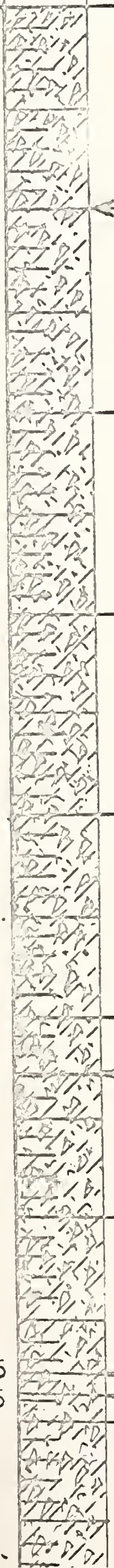
Core Log No. 497
Project No. F-217(11)
Hole No. 7
Termini Livingston
Date Taken March 11,12,15,16, 1965
Location 293' Lt. Sta. 1572+75
Structure Landslide
Party Chief Swanson
Others Horacek - Stevens

Miscellaneous Data
Depth of Hole 101.5 ft.
Rock
Wt. of Hammer 140# & 300#
Average Fall of Hammer 30"
Elev. of Ground Water 51.4 ft.

ratification Depth	*Description of Materials Type, Color & Consistency*
	Brown sandy silt with limestone fragments.
10.0	Slightly damp.
	Brown sandy silt with limestone fragments.
53.0	Damp.
	Brown sandy silt with limestone fragments.
67.5	Soft strata.
68.5	Brown sandy silt with limestone fragments.



Remarks

Total BX Casing - 75.4 ft.

Total 7" Augers - 53.0 ft.

2" Standard Penetration Test - 140# Hammer

Casing Blows	*Penet-ration*	*Rotary Drilling*	
13/21/19	1.5	@	5.0 to 6.5'
13/15/19	1.5	@	10.0 to 11.5
18/17/21	1.5	@	15.0 to 16.5
14/16/21	1.5	@	20.0 to 21.5
10/13/18	1.5	@	25.0 to 26.5
18/24/27	1.5	@	30.0 to 31.5
12/12/18	1.5	@	35.0 to 36.5
12/16/18	1.5	@	40.0 to 41.5
12/20/22	1.5	@	45.0 to 46.5
24/50/ R	1.0	@	50.0 to 51.0
35/37/46	1.5	@	55.0 to 56.5
49/50/ R	0.9	@	60.0 to 60.9
49/49/38	1.5	@	65.0 to 66.5
43/50/ R	1.0	@	70.0 to 71.0
25/ R	0.0	@	75.0' No Penetration
25/20/19	1.5	@	90.0 to 91.5
46/50/ R	0.9	@	95.0 to 95.9
16/31/42	1.5	@	100.0 to 101.5

Drilled with 7" augers from 0.0' to 53.0'

Drilled with Blue Demon bit from 85.0' to 100.0'

Cored with rigid barrel, fine diamond bit from 75.0' to 85.0' 3% recovery.

Elevation and location set by Livingston Engineering crew.

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Core Log No. 497 Project No. F-217(11) Hole No. 7
Termini Livingston Date Taken
Location Structure
Party Chief Others

tratification			Description of Materials Type, Color & Consistency	Casing		Rotary Drilling	Miscellaneous Data Depth of Hole Rock Wt. of Hammer Average Fall of Hammer Elev. of Ground Water.
	Depth 80.0	Legend		Blows	Penet-ration		Remarks
			Brown sandy silt with limestone fragments.				
	89.0		Hard grey-green sandy shale.				
	101.		Bottomed hole in hard grey-green sandy shale.				
			Three boxes core.				

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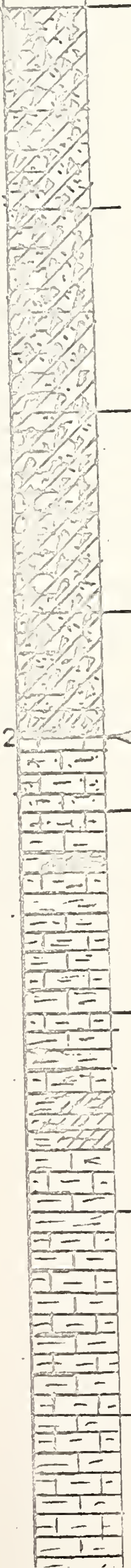
Core Log No. 498
Project No. F-217(11) Hole No. 8
Termini Livingston - South
Date Taken March 17, 18, 19, 22, 23, 24, 25, 1965
Location 289' Lt. Sta. 1571+42
Structure Landslide
Party Chief Swanson
Others Horacek & Stevens

atification		Description of Materials Type, Color & Consistency	Casing		Rotary Drilling
Depth	Legend		Blows	Penetration	

Miscellaneous Data

Depth of Hole	100.0 ft.
Rock	
Wt. of Hammer	140#
Average Fall of Hammer	30"
Elev. of Ground Water	none



Brown silty clay and limestone fragments.

36.2

Hard grey-brown limestone with stratas of tan decomposed limestone and clay.

Remarks

Total BX Casing - 37.4 ft.

Total AX Casing - 90.7 ft.

2" Sample Tube Penetration Test - 140# Hammer

21/17/24	1.5	@	5.0 to 6.5'
12/22/36	1.5	@	10.0 to 11.5
24/50/ R	0.7	@	15.0 to 15.7
11/36/22	1.5	@	20.0 to 21.5
25/ R	0.4	@	25.0 to 25.4
25/ R	0.0	@	29.0 No Penetration
50/ R	0.3	@	35.0 to 35.3

Core Drilling Data - Started Core at 36.8 ft.

Draw	@	40.0'	Core Recovery	94%
Draw	@	45.0'	Core Recovery	45%
Draw	@	55.0'	Core Recovery	83%
Draw	@	65.0'	Core Recovery	37%
Draw	@	75.0'	Core Recovery	35%
Draw	@	85.0'	Core Recovery	15%
Draw	@	95.0'	Core Recovery	17%
Draw	@	100.0'	Core Recovery	10%

Used rigid core barrel with fine diamond bit.

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Core Log No. 498

Project No. F-217(11)

Hole No. 8

Termini Livingston

Date Taken

Location 289' Lt. Sta. 1571+42

Structure , Landslide

Party Chief

Others

tratification			Description of Materials Type, Color & Consistency	Casing		Rotary Drilling	Miscellaneous Data Depth of Hole Rock Wt. of Hammer Average Fall of Hammer Elev. of Ground Water.
El	Depth	Legend		Blows	Penet-ration		Remarks
	80.0		Hard grey-brown limestone with stratas of tan decomposed limestone and clay.				
	100.0		Bottomed hole in hard grey-brown limestone with stratas of tan decomposed limestone and clay.				
			Four boxes core.				

Lab. Form No. 29

MONTANA HIGHWAY COMMISSION   Page 1 of 4 pages.

Horizontal Log No. 1-65   Project F-217(11)   Hole No. 1

Termini Livingston - South   Date Taken May 27 to June 3, 1965

Location 70.4' Left of Sta. 1572+97.1   Structure Landslide

Driller Gunn   Others Cummings & McComb

REMARKS:

Bearing N 57' 42° W

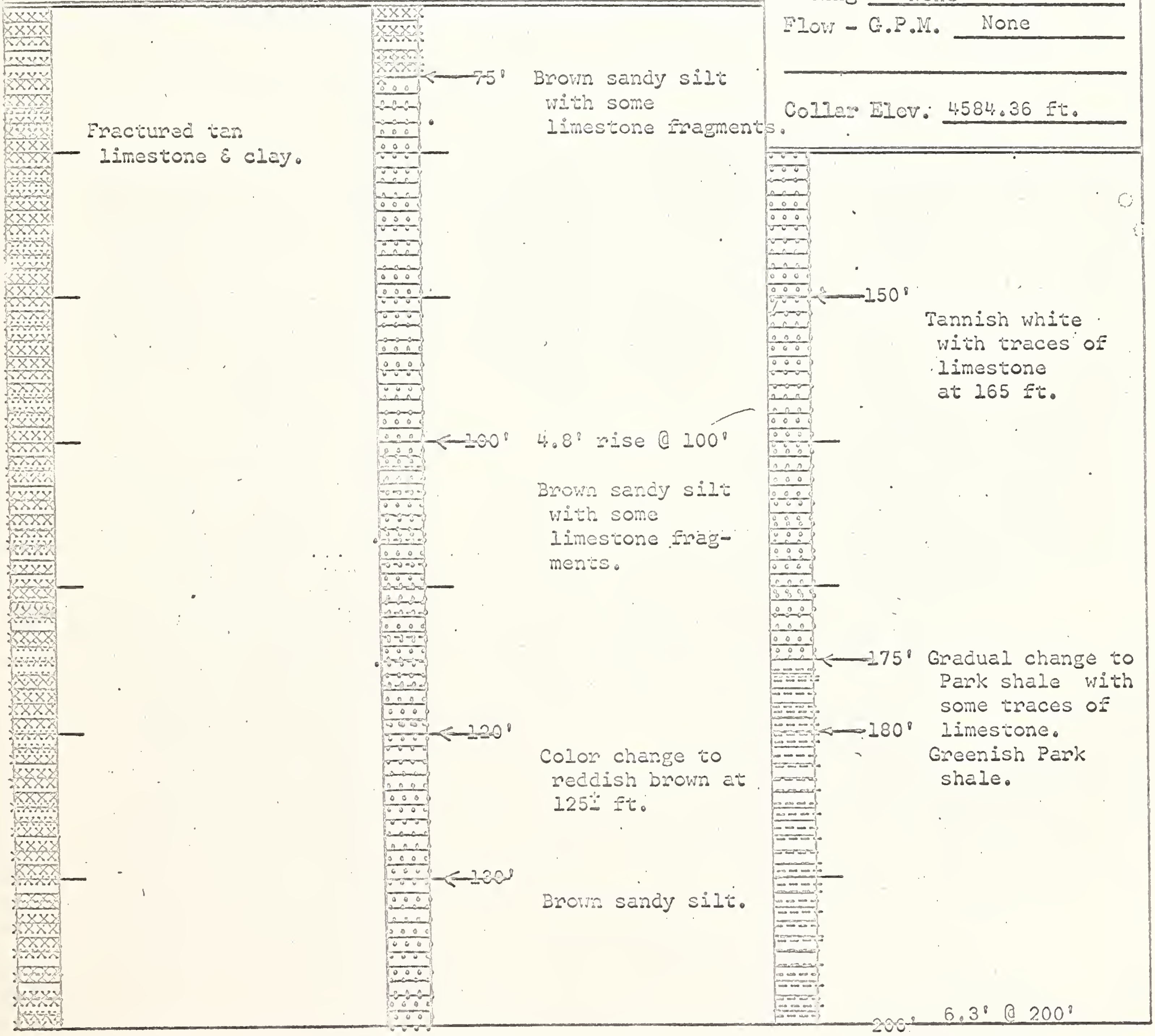
Depth 678 ft.

Grade of Hole 5.95% @ 600'

Casing None

Flow - G.P.M. None

Collar Elev. 4584.36 ft.



Fractured tan limestone & clay.

75' Brown sandy silt with some limestone fragments.

100' 4.8' rise @ 100'

Brown sandy silt with some limestone fragments.

120' Color change to reddish brown at 125½ ft.

130' Brown sandy silt.

150' Tannish white with traces of limestone at 165 ft.

175' Gradual change to Park shale with some traces of limestone.

180' Greenish Park shale.

200' 6.3' @ 200'

Lab. Form No. 29

MONTANA HIGHWAY COMMISSION

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Horizontal Log No. 1-65 Project F-217(11) Hole No. 1

Termini Livingston - South Date Taken May 27 to June 3, 1965

Location Structure

Driller Gunn Others Cummings & McComb

REMARKS:

Bearing

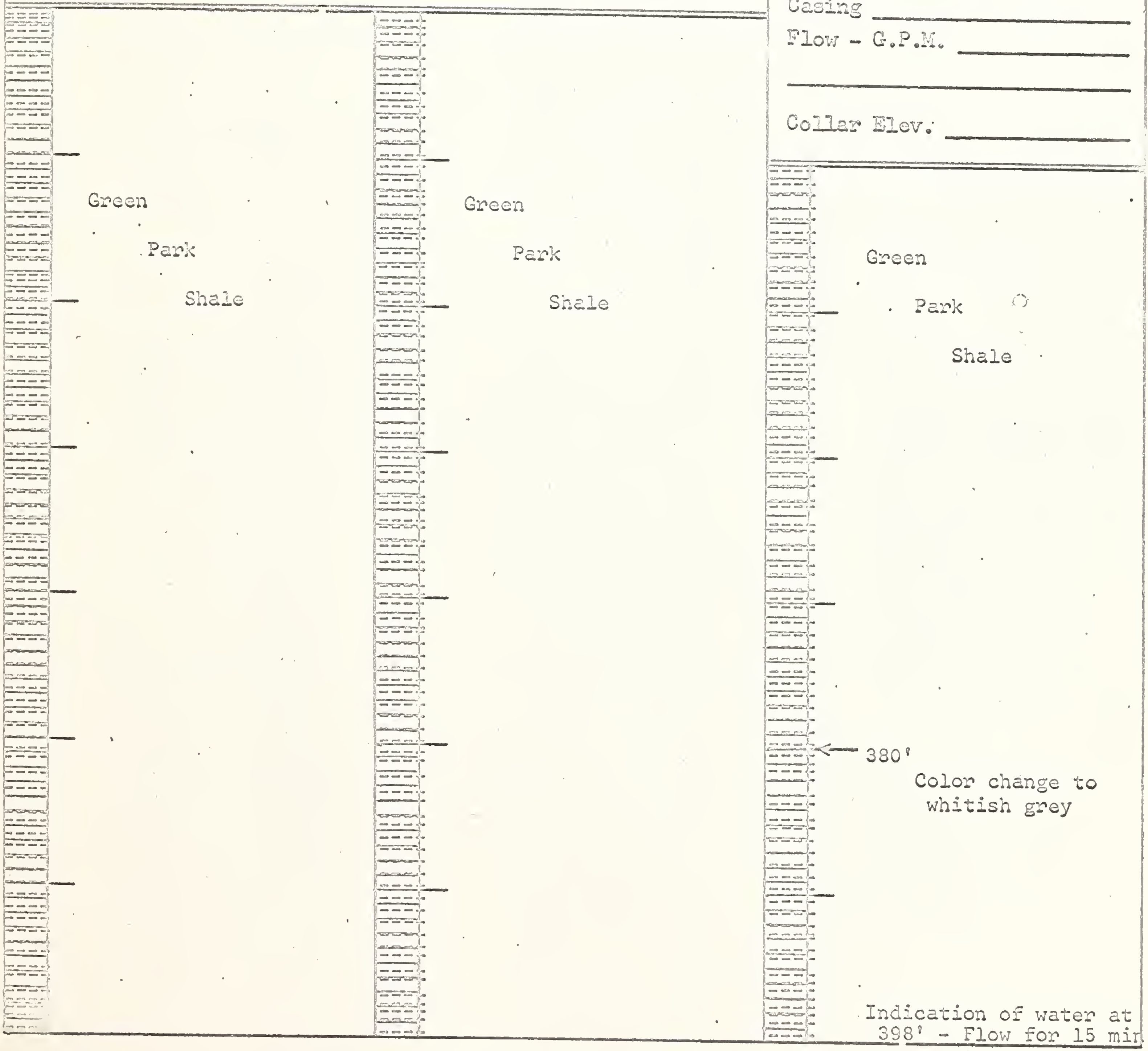
Depth

Grade of Hole

Casing

Flow - G.P.M.

Collar Elev.



380'
Color change to whitish grey

Indication of water at 398' - Flow for 15 min.

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MONTANA HIGHWAY COMMISSION

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Horizontal Log No. 1-65

Project F-217(11)

Hole No. 1

Termini Livingston - South

Date Taken May 27 to June 3, 1965

Location

Structure

Driller Gunn

Others Cummings & McComb

REMARKS:

Bearing

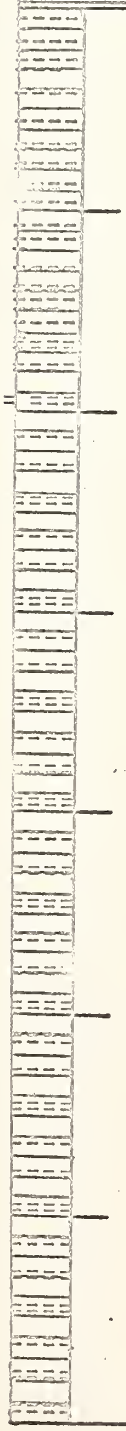
Depth

Grade of Hole

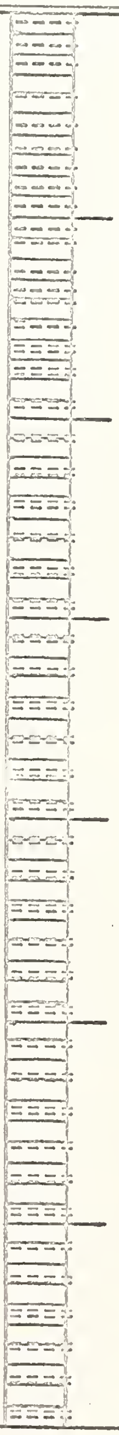
Casing

Flow - G.P.M.

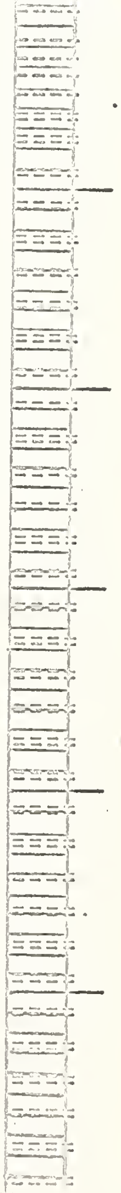
Collar Elev.



Bluish Green Shale



Bluish Green Shale



Traces of red in green shale at 558'

Lab. Form No. 29

MONTANA HIGHWAY COMMISSION Page 4 of 4 pages

Horizontal Log No. 1-65 Project F-217(11) Hole No. 1

Termini Livingston - South Date Taken May 27 to June 3, 1965

Location ______ Structure ______

Driller Gunn Others Cummings & McComb

REMARKS: ______

Bearing ______

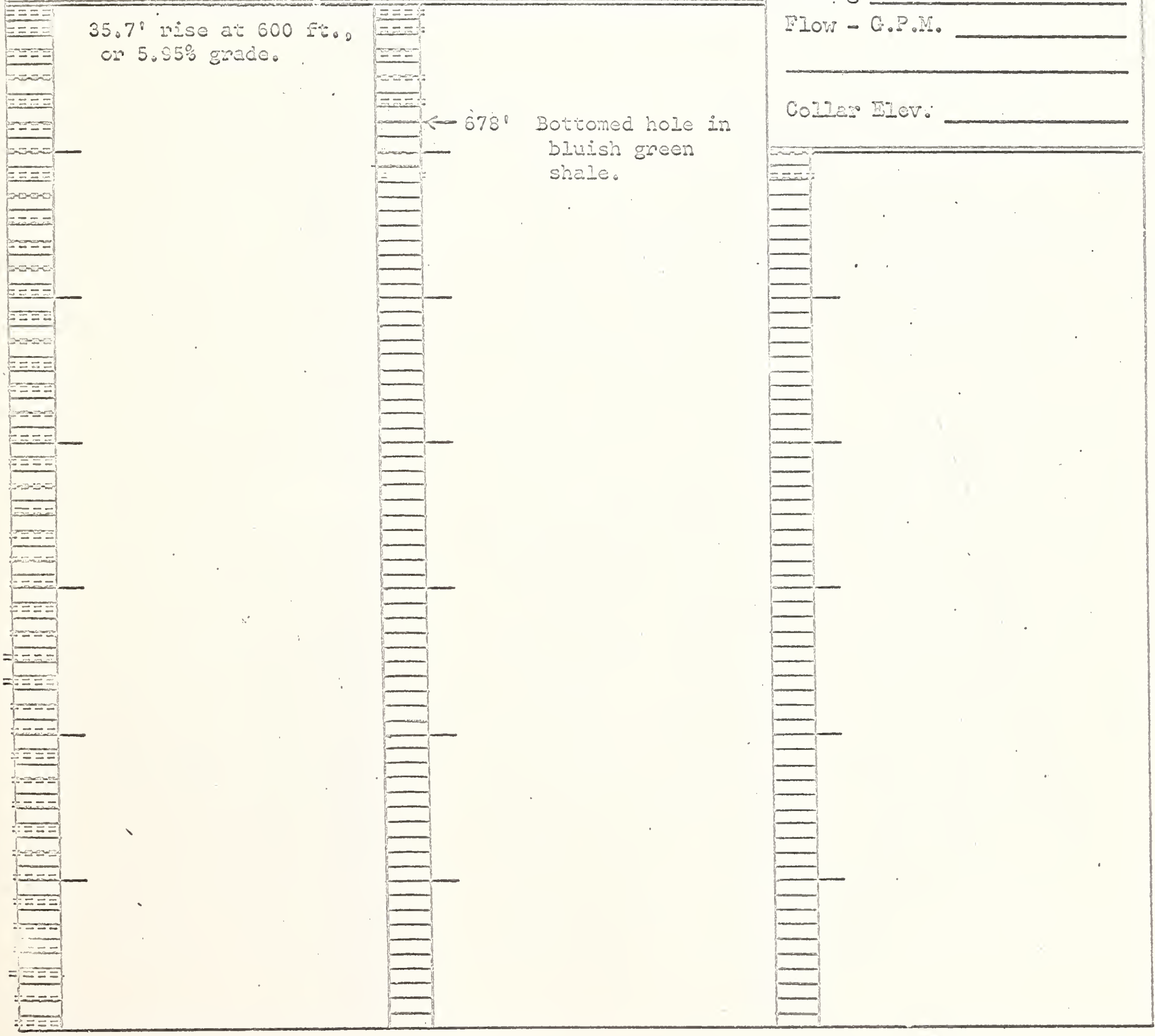
Depth ______

Grade of Hole ______

Casing ______

Flow - G.P.M. ______

Collar Elev. ______



35.7' rise at 600 ft., or 5.95% grade.

678' Bottomed hole in bluish green shale.

Lab. Form No. 29 .

MONTANA HIGHWAY COMMISSION Page 1 of 2 pages

Horizontal Log No. 2-65 Project F-217(11) Hole No. 2

Termini Gardiner - Livingston Date Taken June 4 to 17, 1965

Location 65.6' Lt. P.O.S.T. Sta.1573+26± Structure Landslide

Driller Gunn Others Cummings & McComb

REMARKS:

Bearing 89°-52-1/2' West

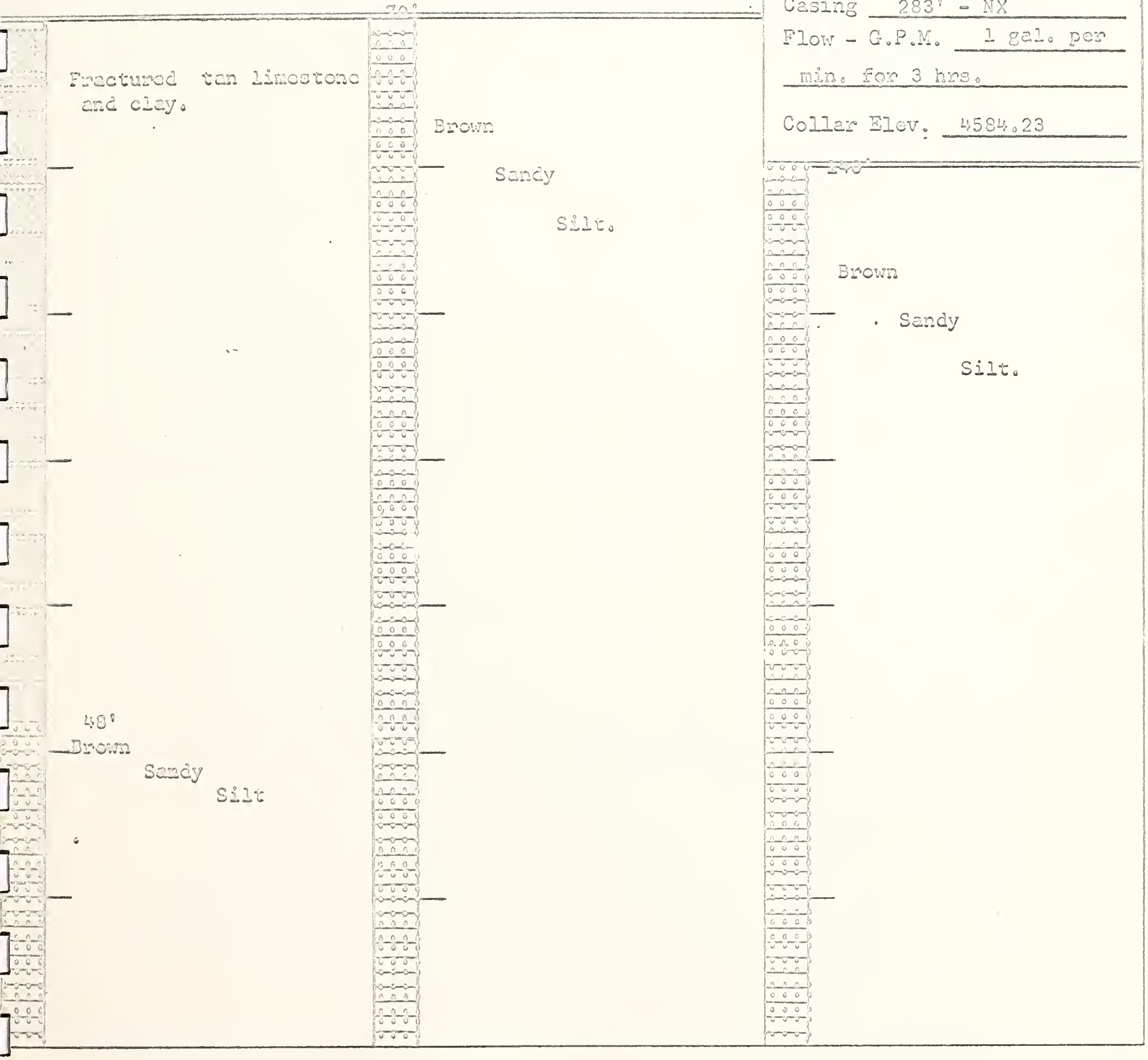
Depth 320 ft.

Grade of Hole 3% at 200 ft.

Casing 283' - NX

Flow - G.P.M. 1 gal. per min. for 3 hrs.

Collar Elev. 4584.23



IGHWAY COMMISSION Page [illegible] of [illegible] pages

Project F-2[illegible](11) Hole No. 2

Termini Gardiner - Livingston Date Taken June 4 to 17, 1965

Location Structure Landslide

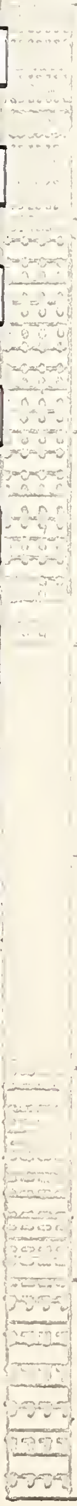
Driller Gunn Others Cummings & McComb

REMARKS:

Bearing
Depth
Grade of Hole
Casing
Flow - G.P.M.

Collar Elev.

200'



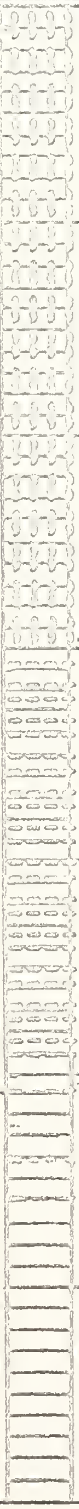
Brownish yellow fractured limestone & brown sandy silt.

Hard Limestone.

Bluish-green shale; probable dip in hole.

Dark green & yellow sand; lost circulation.

270'



Coarse, green and yellow sand.

Hard Sandy Shale.

320' Bottomed hole in hard sandy shale.

Lab. Form No. 29

MONTANA HIGHWAY COMMISSION Page 1 of 3 pages

Horizontal Log No. 3-65 Project F-217(11) Hole No. 3

Termini Gardiner-Livingston Date Taken June 18 - 28, 1965

Location 65' Lt. Sta. 157[illegible] Structure Landslide

Driller Gunn Others Cummings & McComb

[illegible] 18.5' [illegible]

REMARKS: Sand from 70 to 300 ft. caused caving and loss of drill circulation water.

Bearing [illegible]

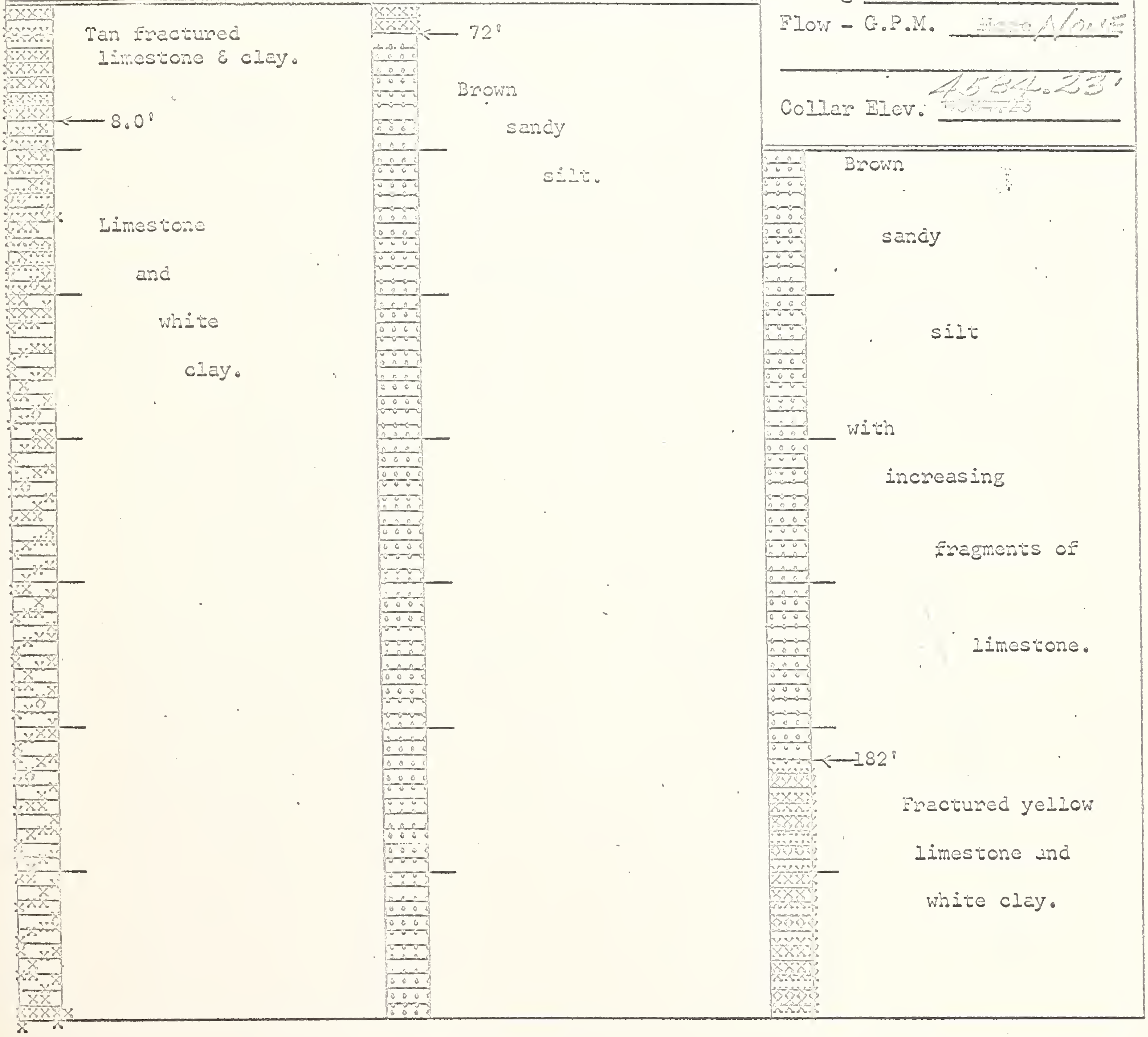
Depth 540'

Grade of Hole [illegible]

Casing

Flow - G.P.M. None

Collar Elev. 4584.23'



Tan fractured limestone & clay.

Limestone and white clay.

Brown sandy silt.

Brown sandy silt with increasing fragments of limestone.

Fractured yellow limestone and white clay.

Lab. Form No. 29

MONTANA HIGHWAY COMMISSION Page 2 of 3 pages

Horizontal Log No. 3-65 Project F-217(11 Hole No. 3

Termini Date Taken June 18 - 28, 1965

Location Structure

Driller Others

REMARKS: Sand from 70 to 300 ft. caused caving and loss of drill circultation water.

Sand sluff between 70 & 300 ft.

Bearing

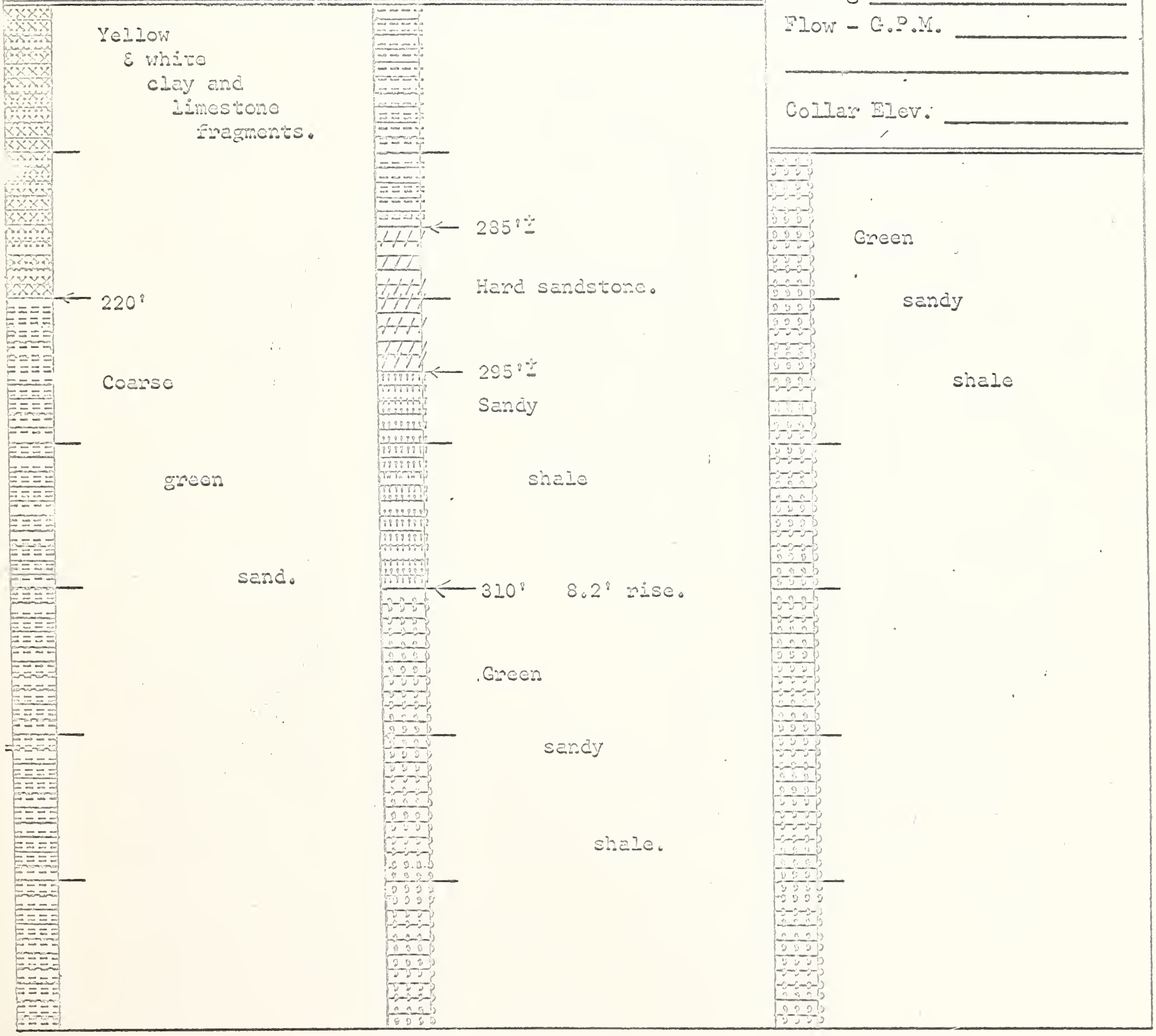
Depth

Grade of Hole

Casing

Flow - G.P.M.

Collar Elev.



Lab. Form No. 29

MONTANA HIGHWAY COMMISSION Page 3 of 3 pages

Horizontal Log No. 3-65 Project F-217(11) Hole No. 3

Termini Gardiner-Livingston Date Taken June 18 - 28, 1965

Location Structure

Driller Others

REMARKS: Sand sluffing between 70' and 300' making it difficult to maintain circulation

Bearing

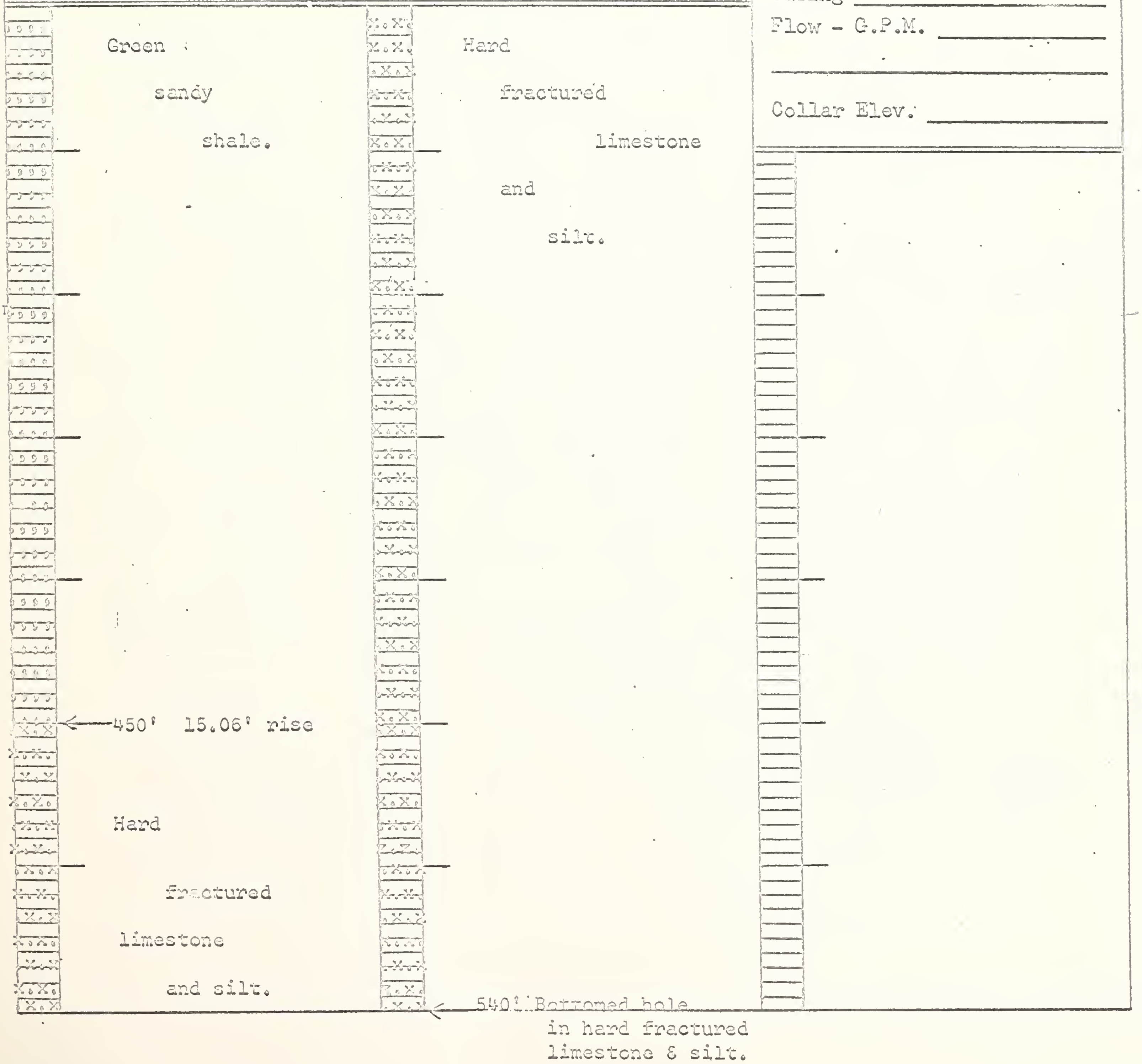
Depth

Grade of Hole

Casing

Flow - G.P.M.

Collar Elev.


Green sandy shale.
450' 15.06' rise
Hard fractured limestone and silt.
Hard fractured limestone and silt.
540' Bottomed hole in hard fractured limestone & silt.

Lab. Form No. 29

MONTANA HIGHWAY COMMISSION Page 1 of 2 pages

Horizontal Log No. 4-65 Project F-217(11) Hole No. 4

Termini Gardiner - Livingston Date Taken June 29 to July 16, 1965

Location [illegible] Structure Landslide

Driller Gunn & Cummings Others McComb & Deegan

REMARKS: Casing - 183 ft. of 2" perforated pipe and 90 ft. of 2" solid pipe

Bearing N.51°-33.5' ~~N-60° 53-1/2' W~~

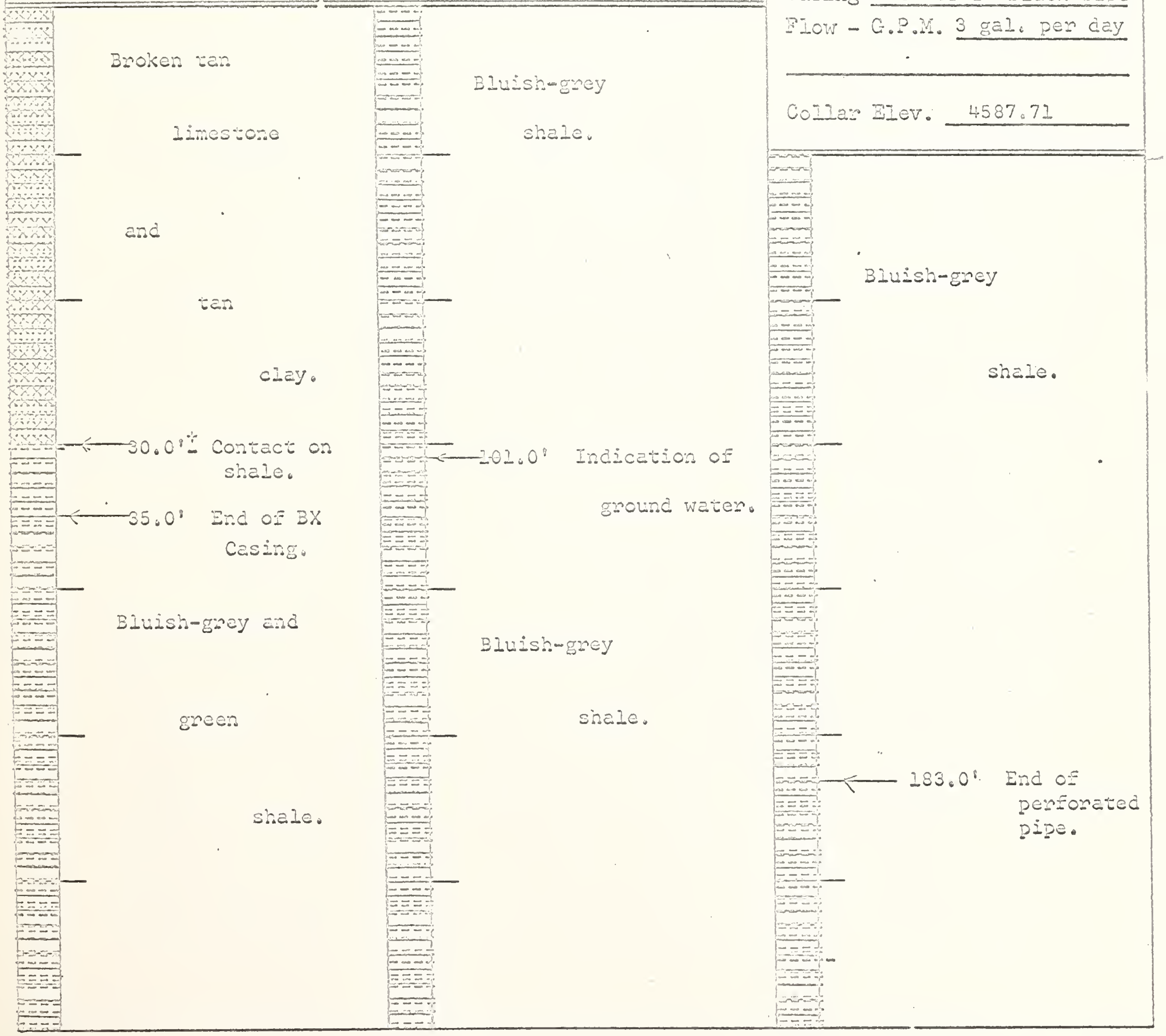
Depth 285 ft.

Grade of Hole 4.2%

Casing 273' of 2" black pipe

Flow - G.P.M. 3 gal. per day

Collar Elev. 4587.71



Broken tan limestone and tan clay.

30.0'± Contact on shale.

35.0' End of BX Casing.

Bluish-grey and green shale.

Bluish-grey shale.

101.0' Indication of ground water.

Bluish-grey shale.

Bluish-grey shale.

183.0' End of perforated pipe.

Lab. Form No. 29

MONTANA HIGHWAY COMMISSION Page 1 of 2 pages

Horizontal Log No. 4-65 Project F-217(11) Hole No. 4

Termini Gardiner - Livingston Date Taken June 29 to July 16, 1965

Location [illegible] Structure Landslide

Driller Gunn & Cummings Others McComb & Deegan

REMARKS: Casing - 183 ft. of 2" perforated pipe and 90 ft. of 2" solid pipe

Bearing N.31°-33.5' ~~N 60° 53-1/2' W~~

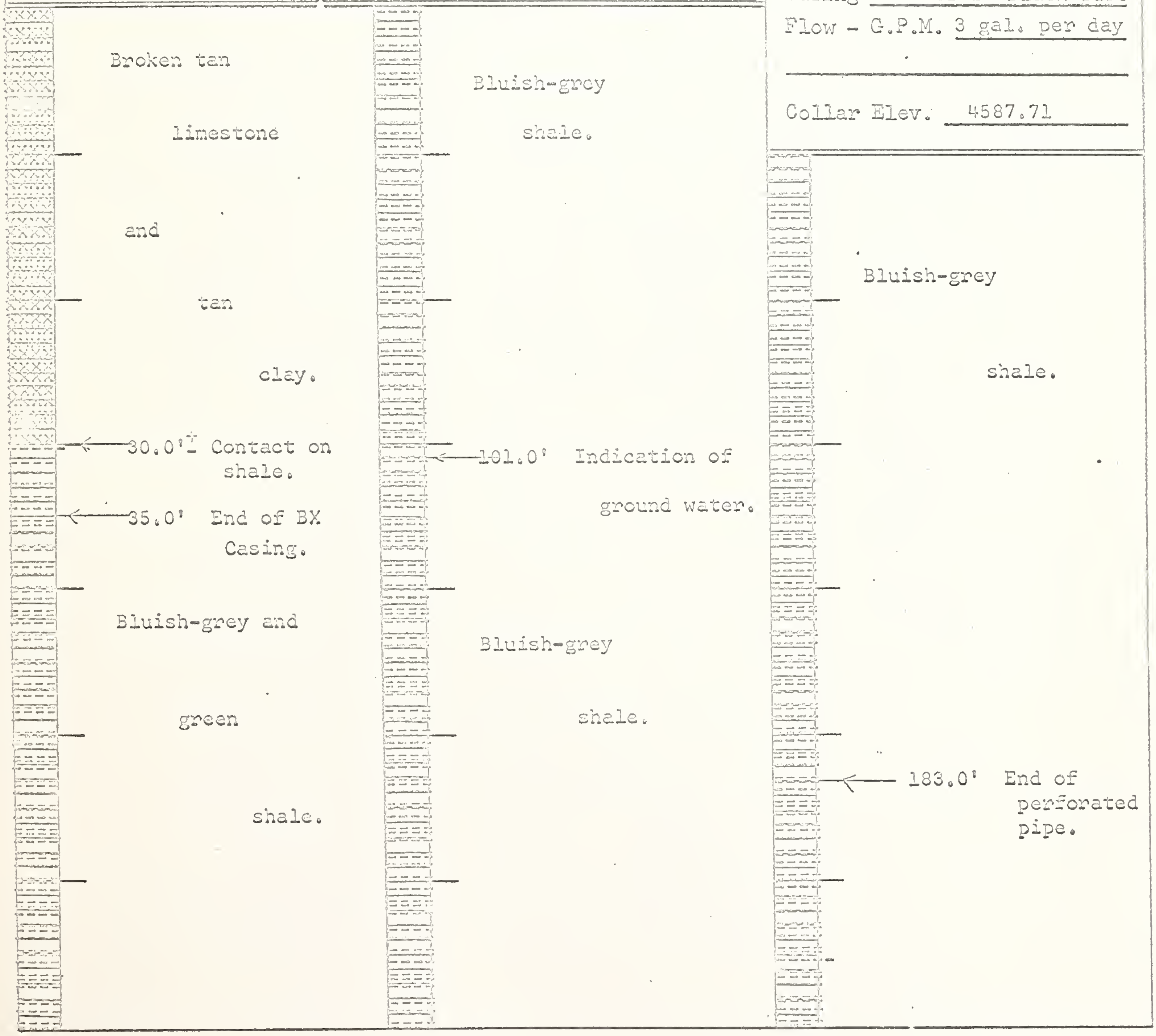
Depth 285 ft.

Grade of Hole 4.2%

Casing 273' of 2" black pipe

Flow - G.P.M. 3 gal. per day

Collar Elev. 4587.71



Broken tan limestone and tan clay.

30.0'± Contact on shale.

35.0' End of BX Casing.

Bluish-grey and green shale.

Bluish-grey shale.

101.0' Indication of ground water.

Bluish-grey shale.

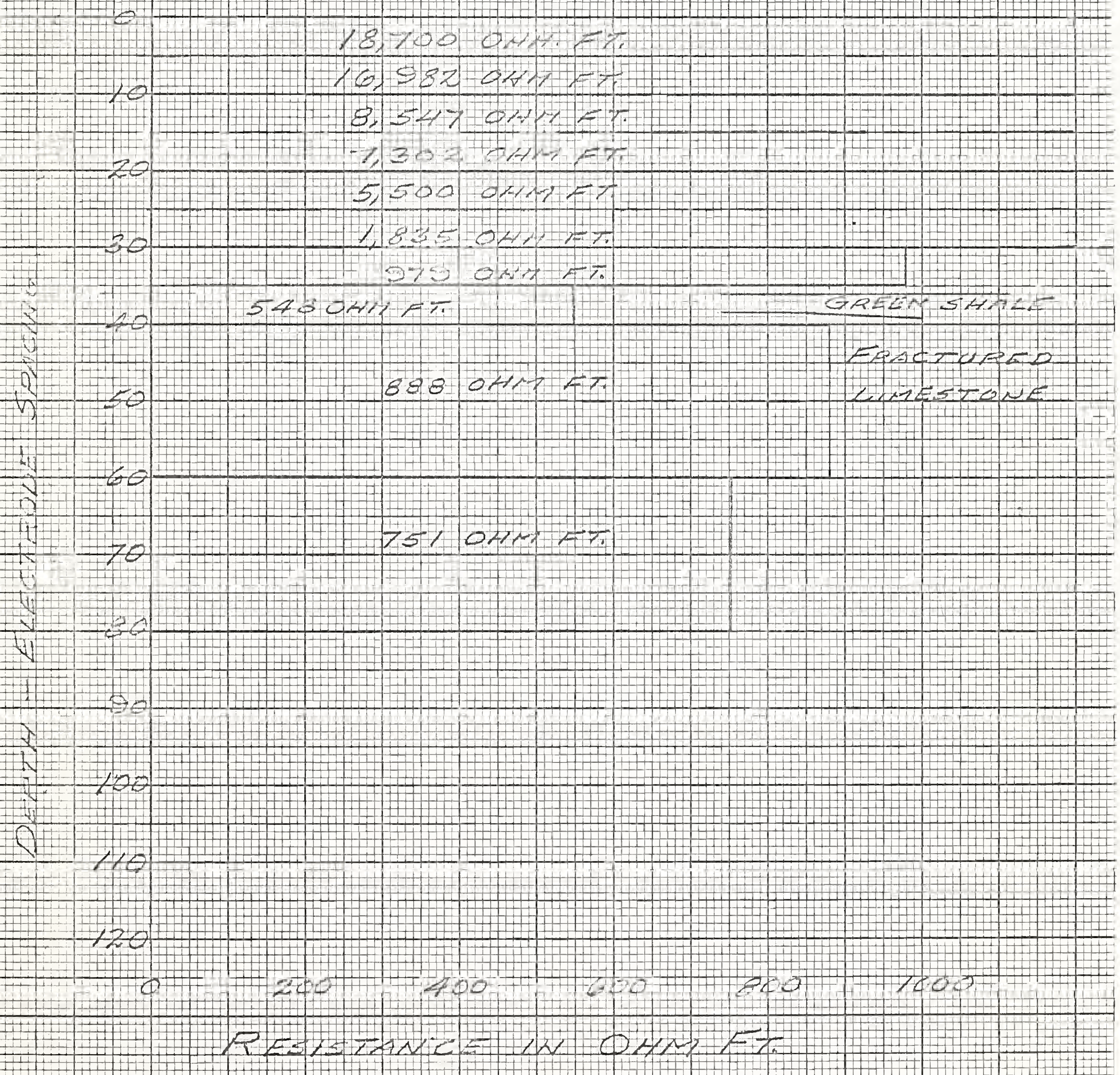
Bluish-grey shale.

183.0' End of perforated pipe.

LIVINGSTON LANDSLIDE

BAR GRAPH RESISTIVITY LOG

CORE DRILL HOLE NO. 1

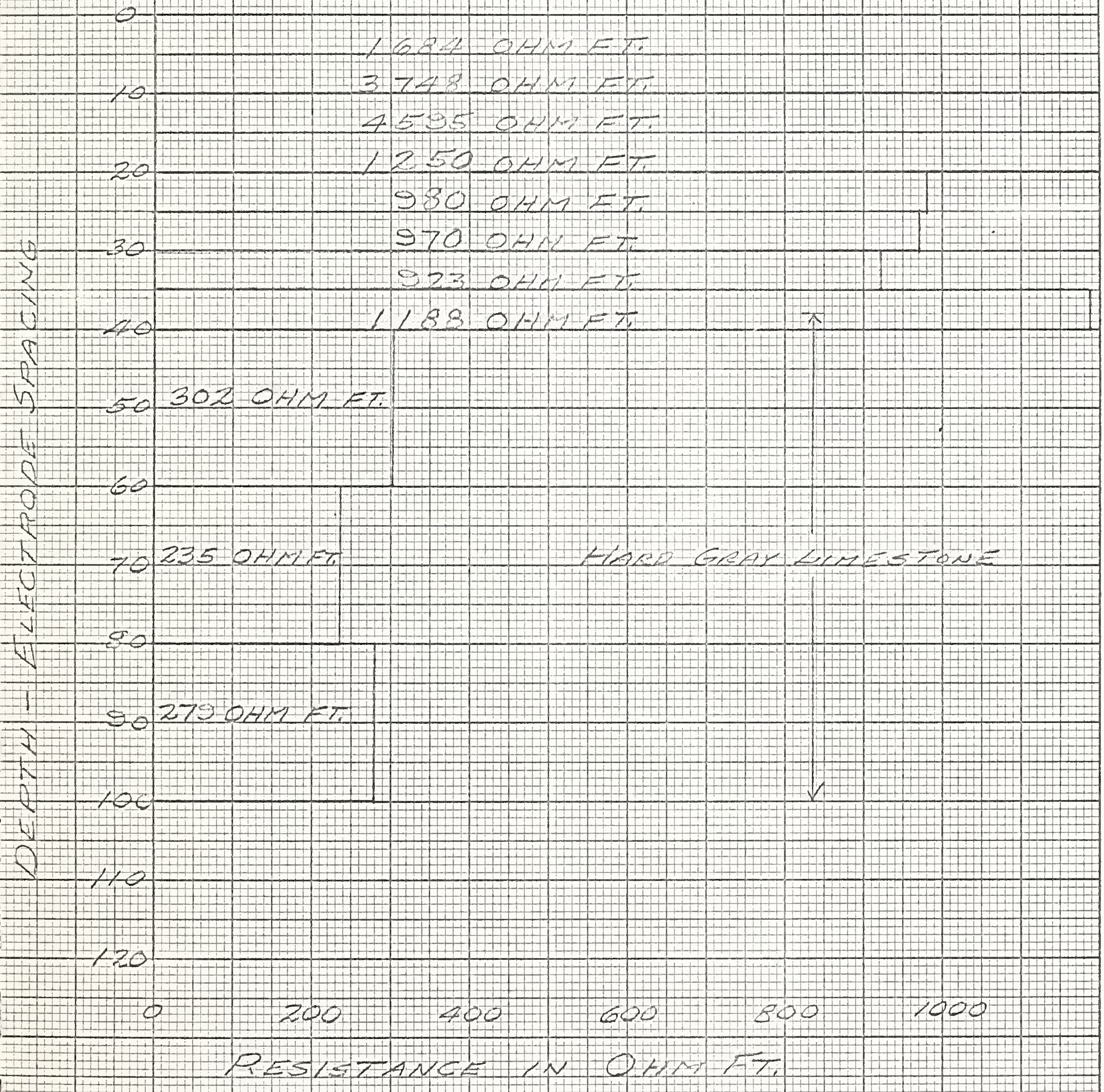


REF. NO. 1

LIVINGSTON LANDSLIDE

BAR GRAPH RESISTIVITY LOG

CORE DRILL HOLE No. 2



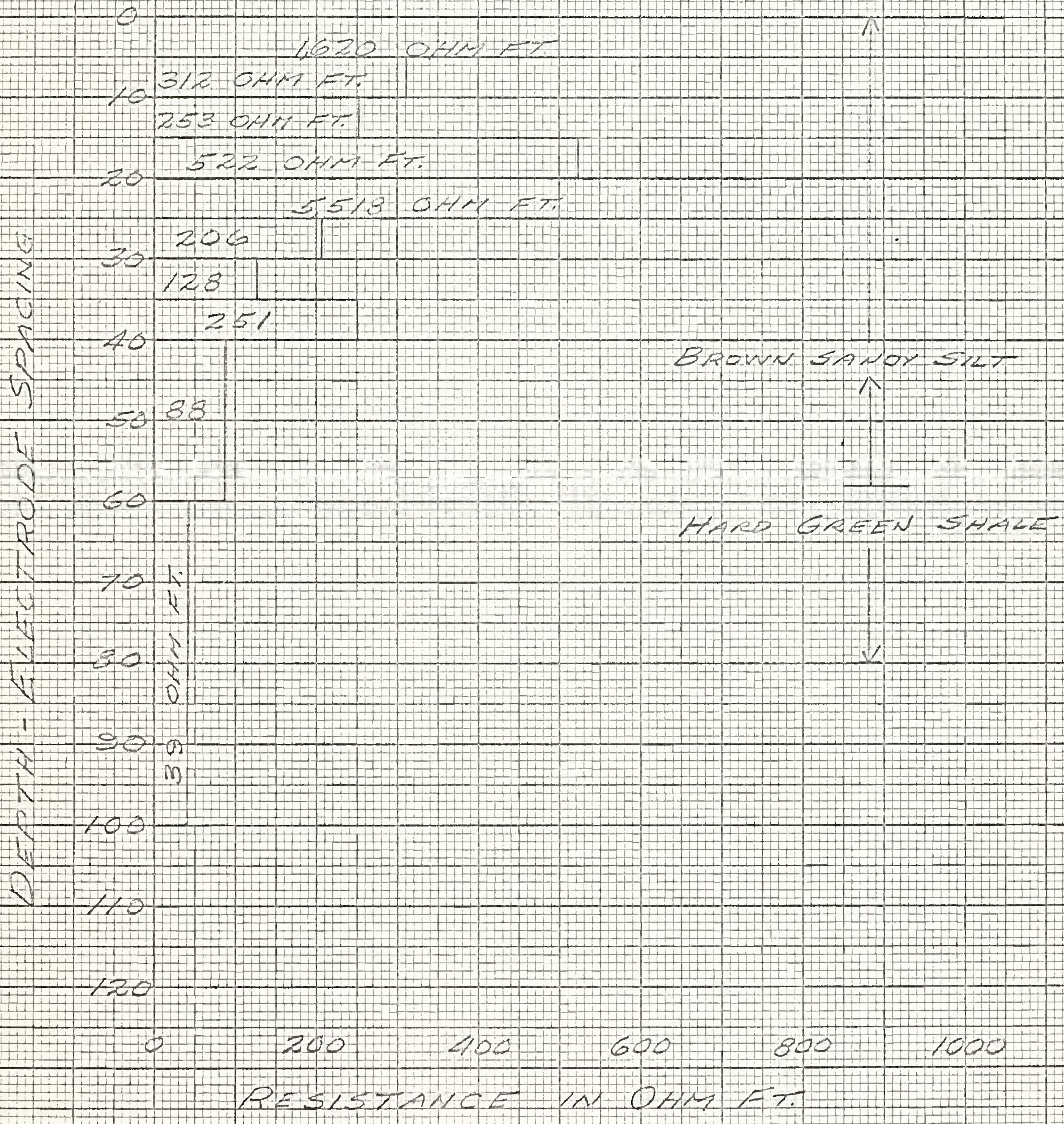
REF. No. 1

K+E 10 X 10 TO THE ½ INCH 358-11L
KEUFFEL & ESSER CO. MADE IN U.S.A.

LIVINGSTON LANDSLIDE

BAR GRAPH RESISTIVITY LOG

CORE DRILL HOLE NO. 3

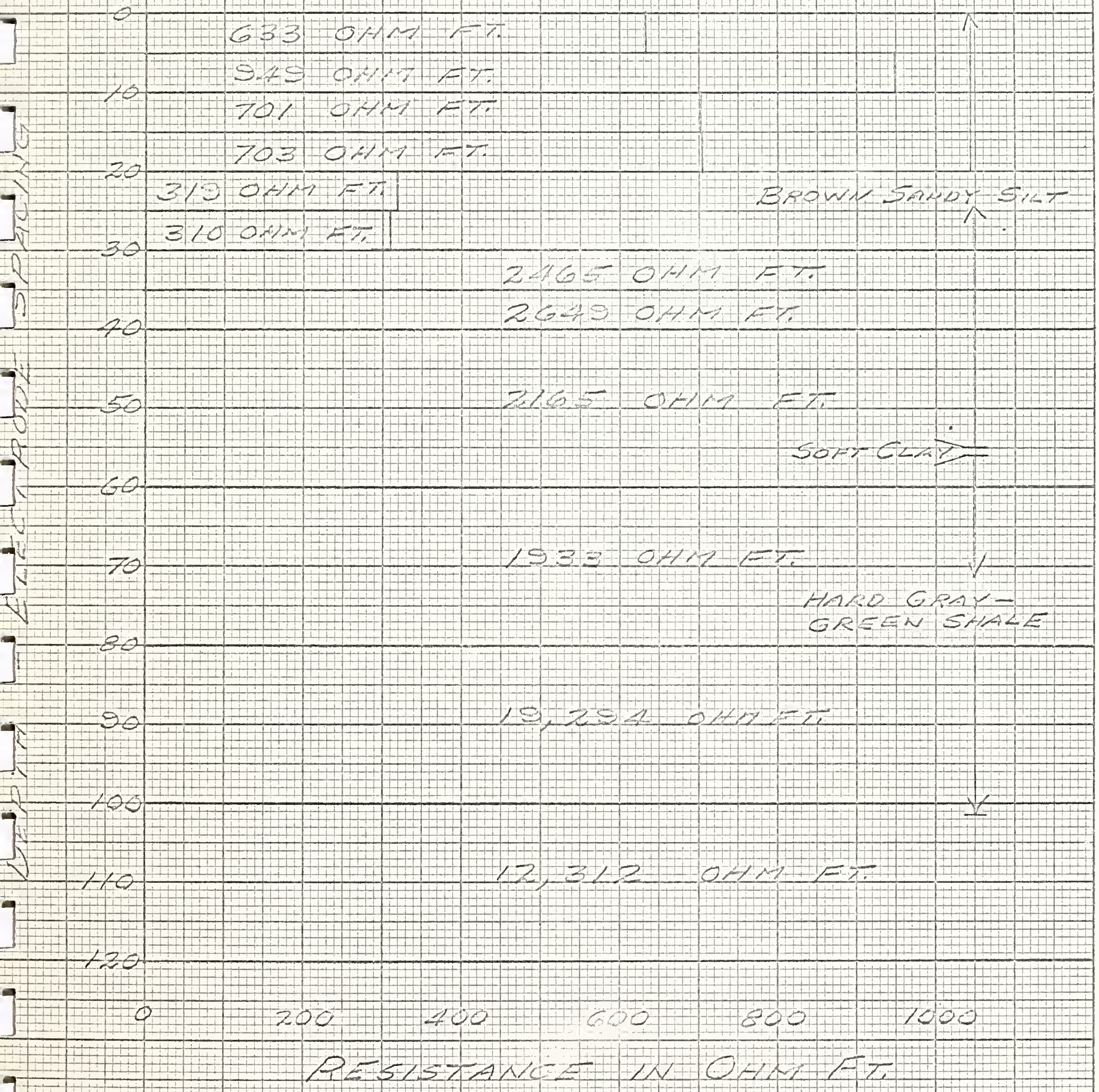


REF. NO. 1

LIVINGSTON LANDSLIDE

BAR GRAPH RESISTIVITY LOG

CORE DRILL HOLE NO. 4



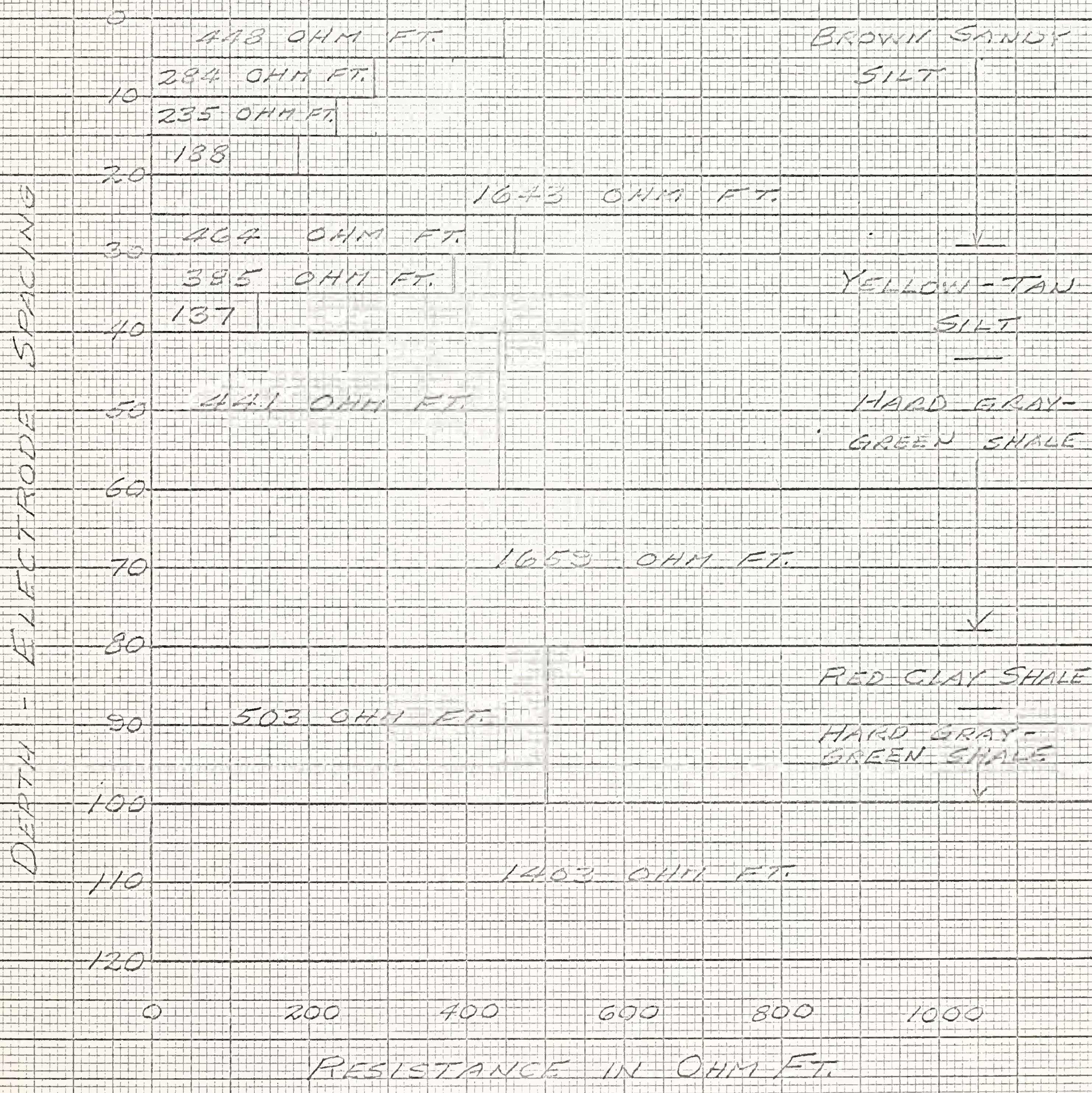
REF. NO. 1

K+E 10 X 10 TO THE ½ INCH
KEUFFEL & ESSER CO.
358-11L
MADE IN U.S.A.

LIVINGSTON LANDSLIDE

BAR GRAPH RESISTIVITY LOG

CORE DRILL HOLE NO. 5



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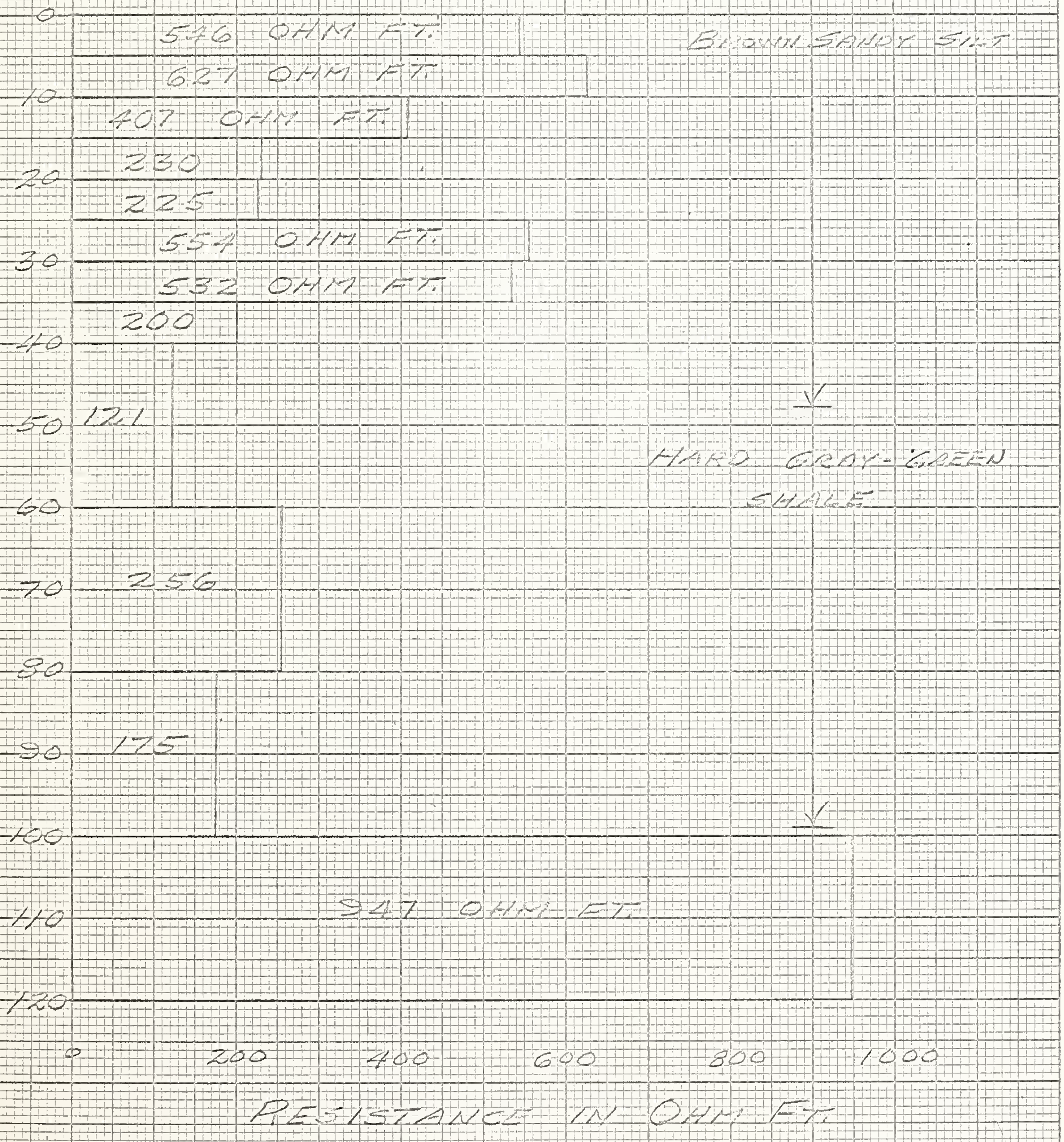
LIVINGSTON LANDSLIDE

BAR GRAPH RESISTIVITY LOG

CORE DRILL HOLE NO. 6



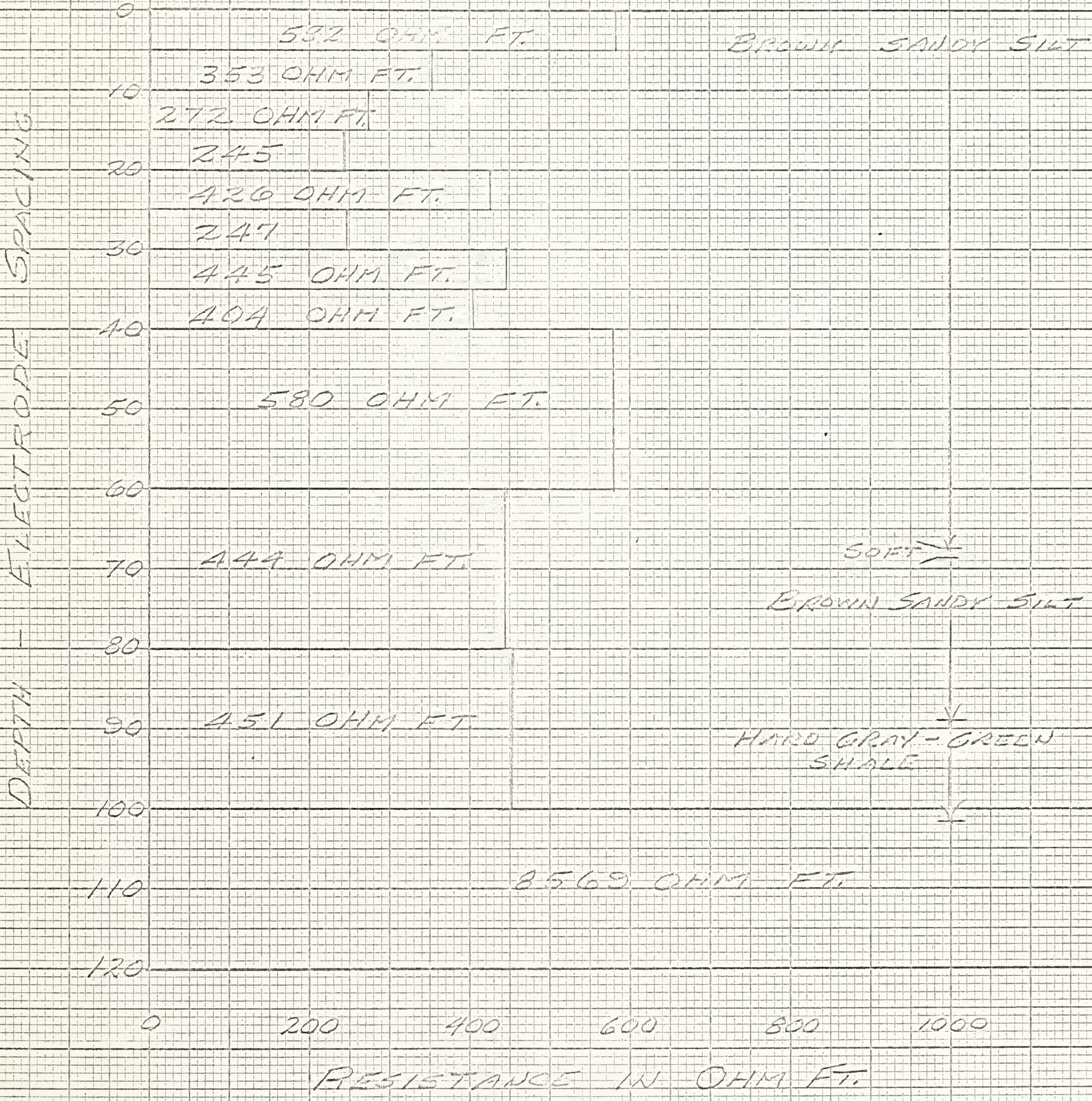
REF. NO. 1

K+E 10 X 10 TO THE ½ INCH KEUFFEL & ESSER CO. 358-11L MADE IN U.S.A.

LIVINGSTON LANDSLIDE

BAR GRAPH RESISTIVITY LOG

CORE DRILL HOLE NO. 7

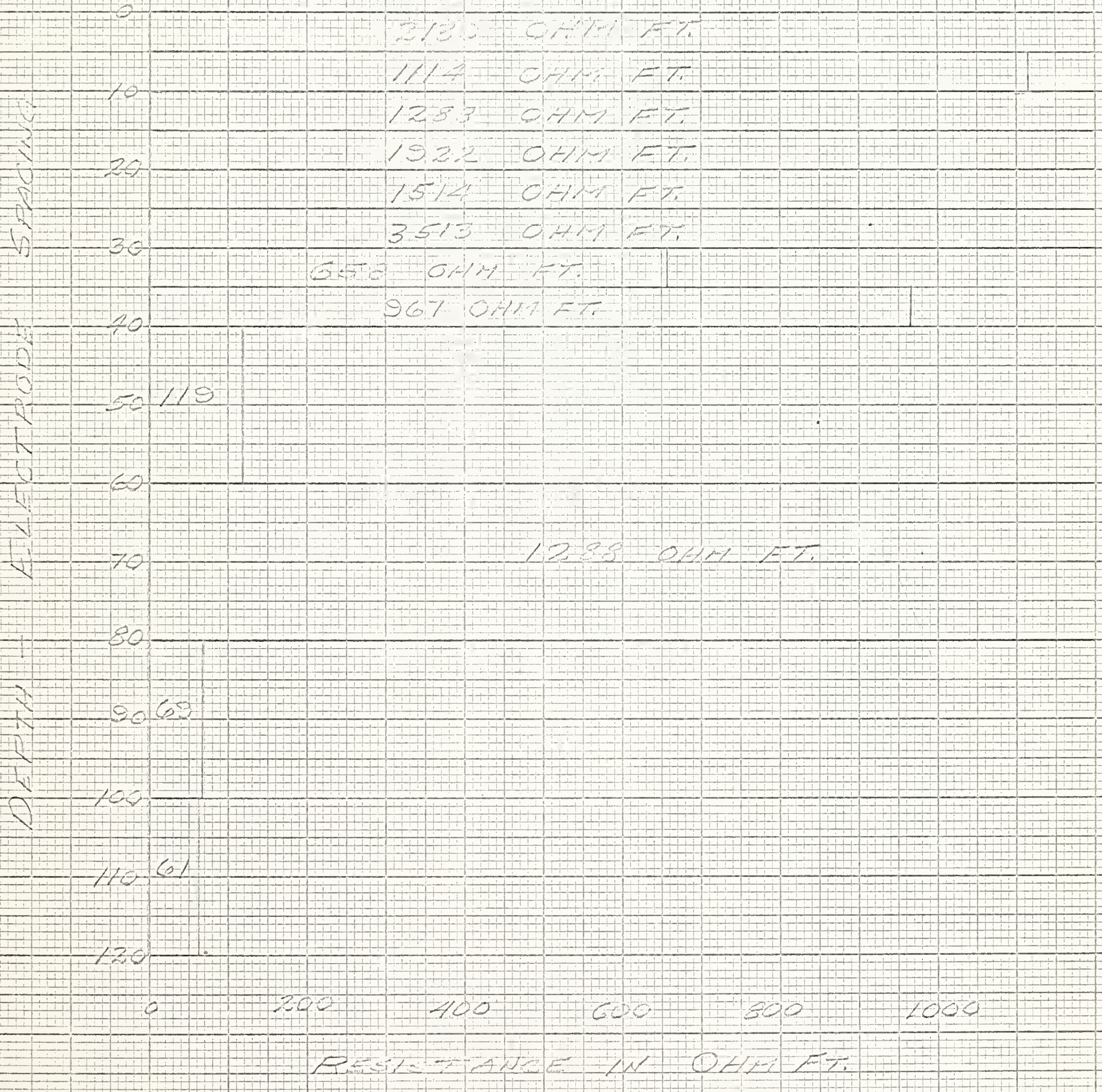


REF. No. 1

LIVINGSTON LANDSLIDE

BAR GRAPH RESISTIVITY LOG

E.R. #1, 522' LT. 1574+00



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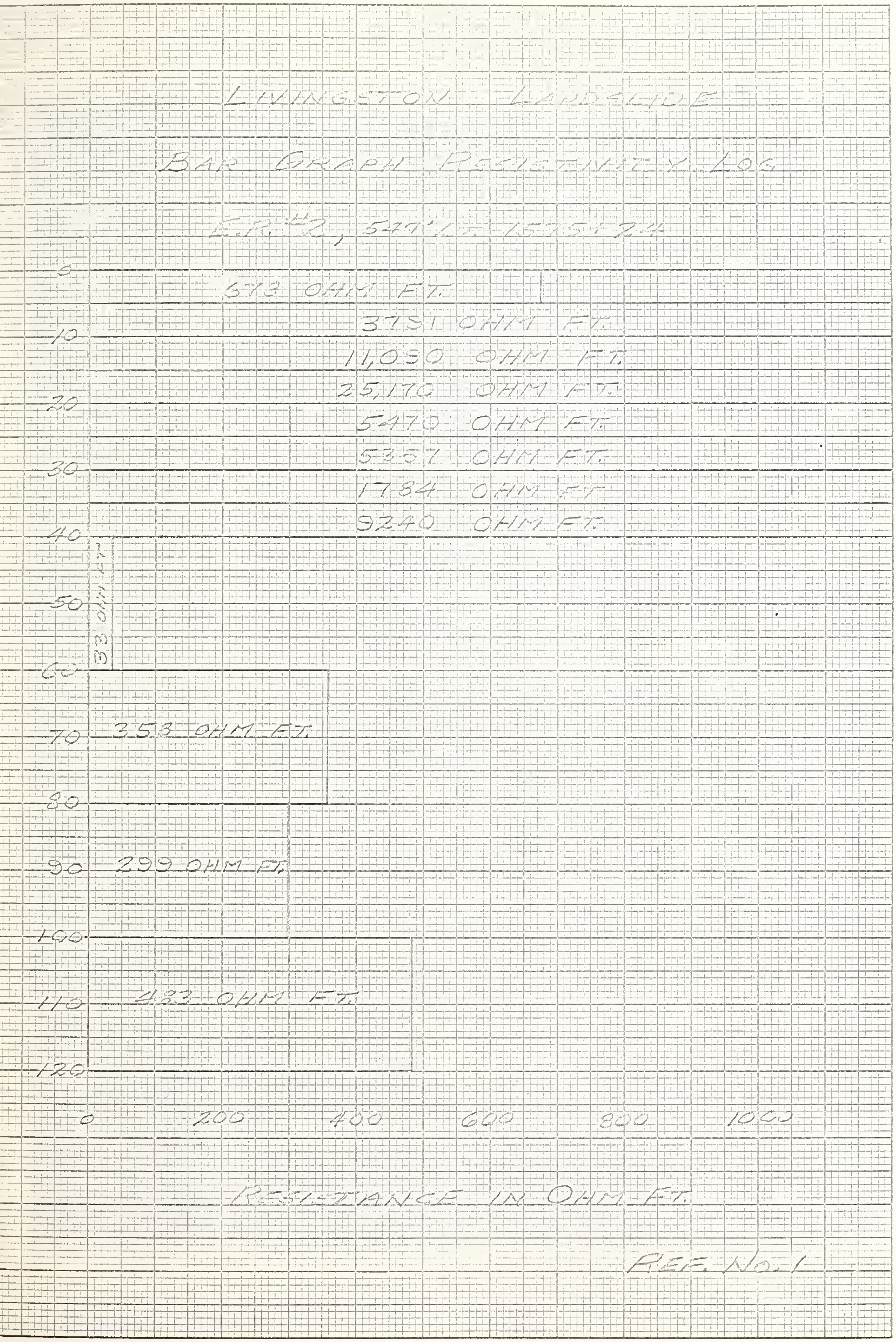


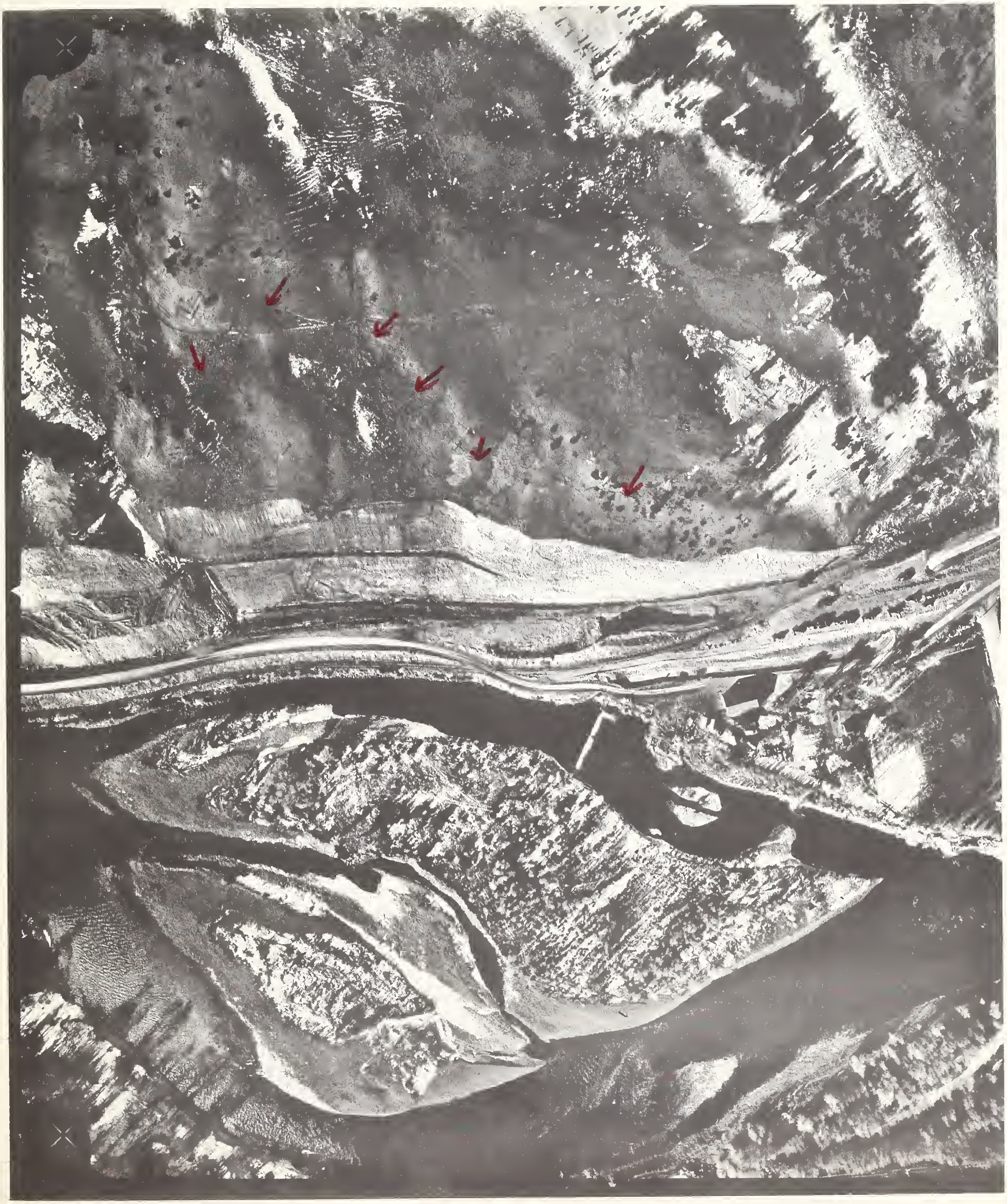
LIVINGSTON LANDSLIDE

BAR GRAPH RESISTIVITY LOG

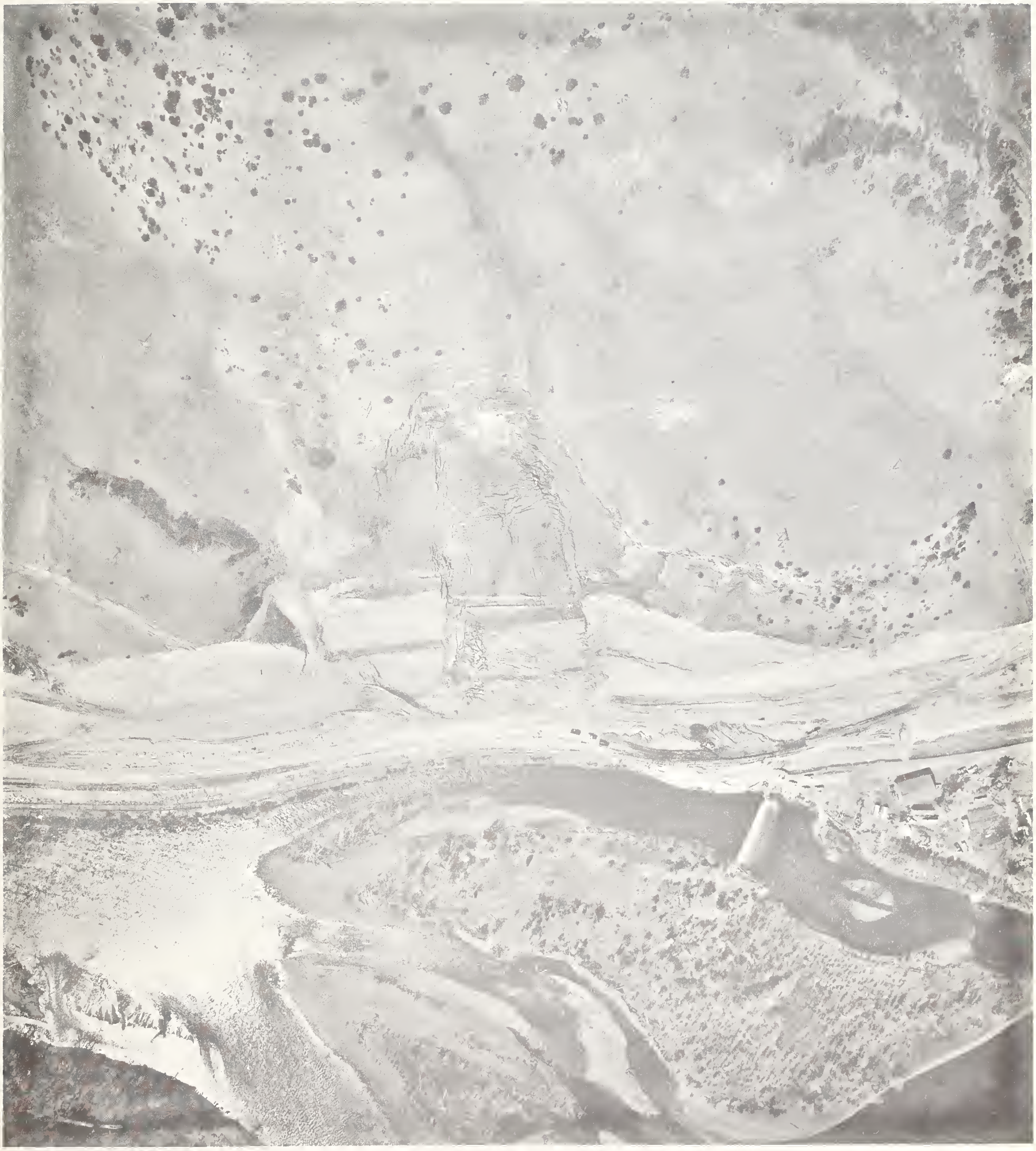
E.R. #2, 547' L.T. 1575+24

REF. NO. 1

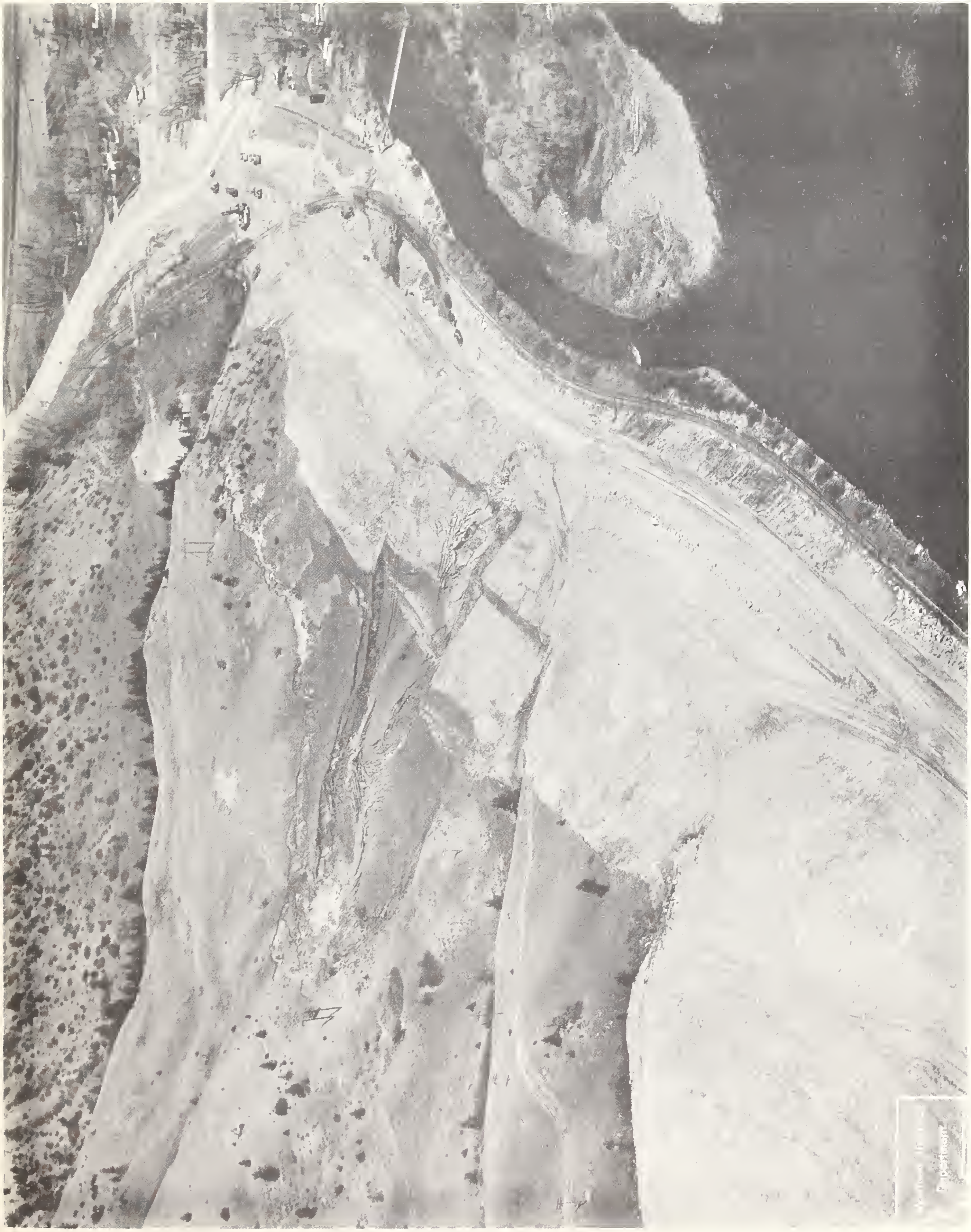
K+E 10 X 10 TO THE ½ INCH
KEUFFEL & ESSER CO.
358-11L
MADE IN U.S.A.



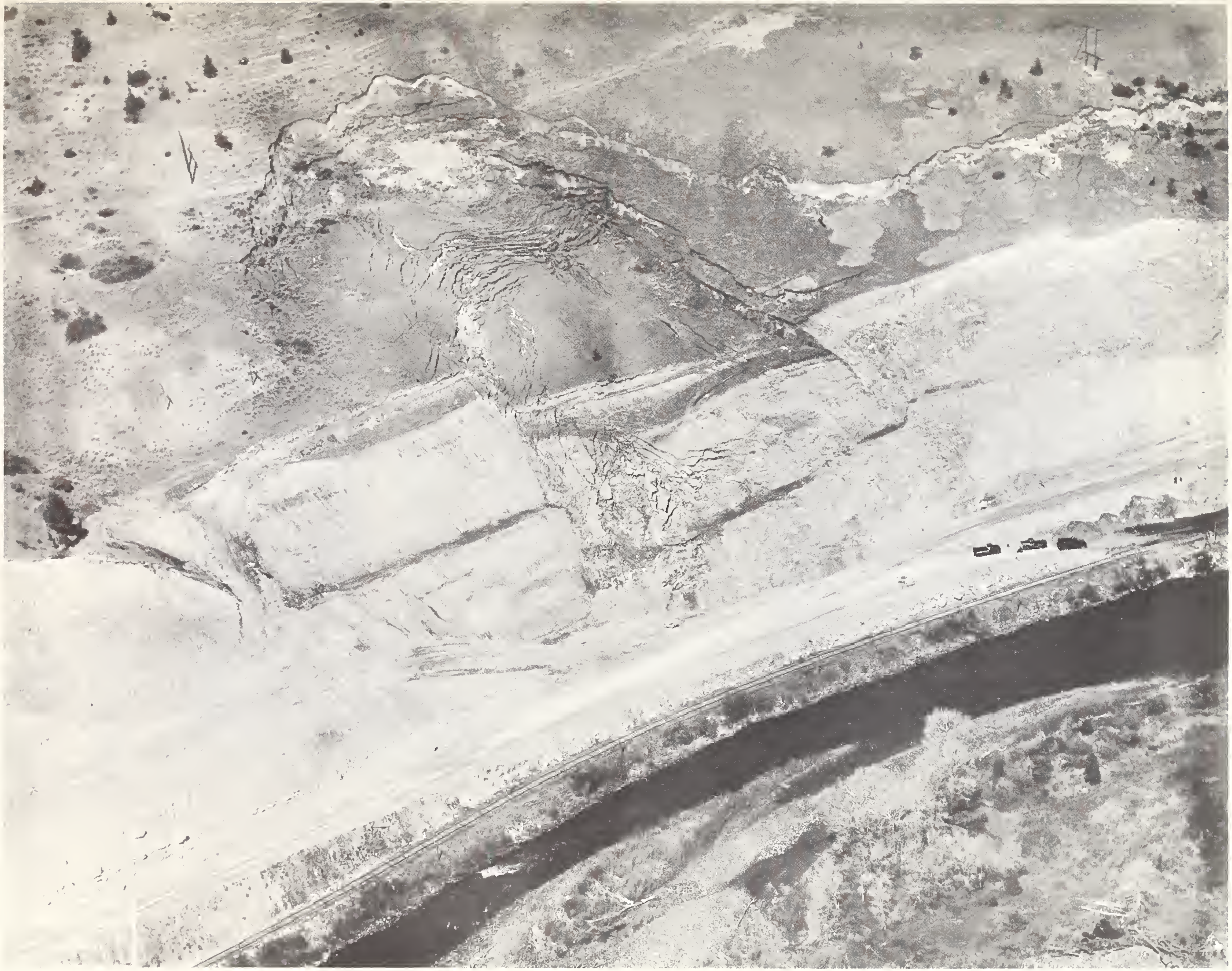
Vertical of general area taken before the large failure. Note arrows pointing to Tension Cracks. Picture taken Jan. 20, 1965.



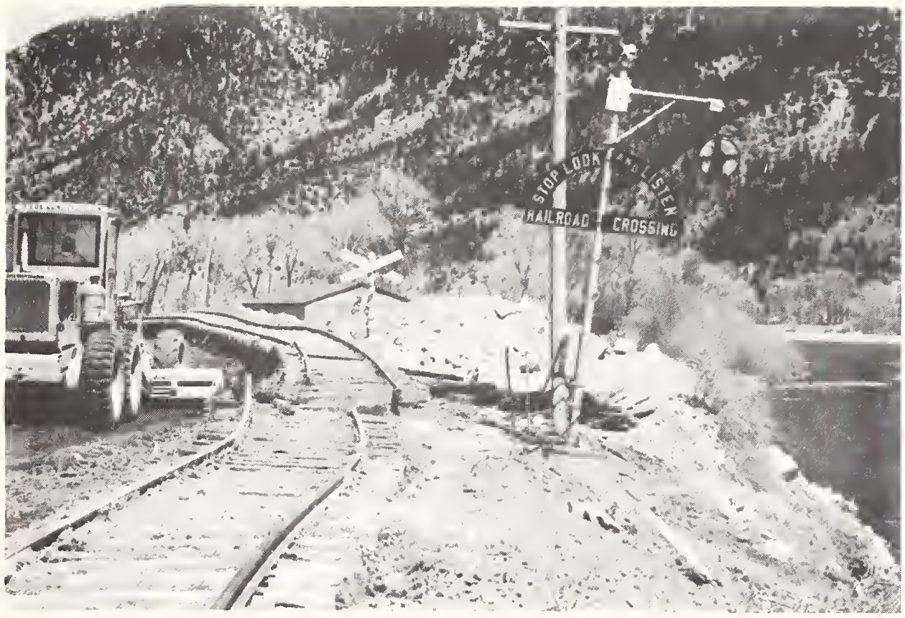
Vertical view of failure taken April 27, 1965. Note development toward the right in previously stable cut slope. Note excavation in vicinity of the diversion structure which relieved the pressure on it.



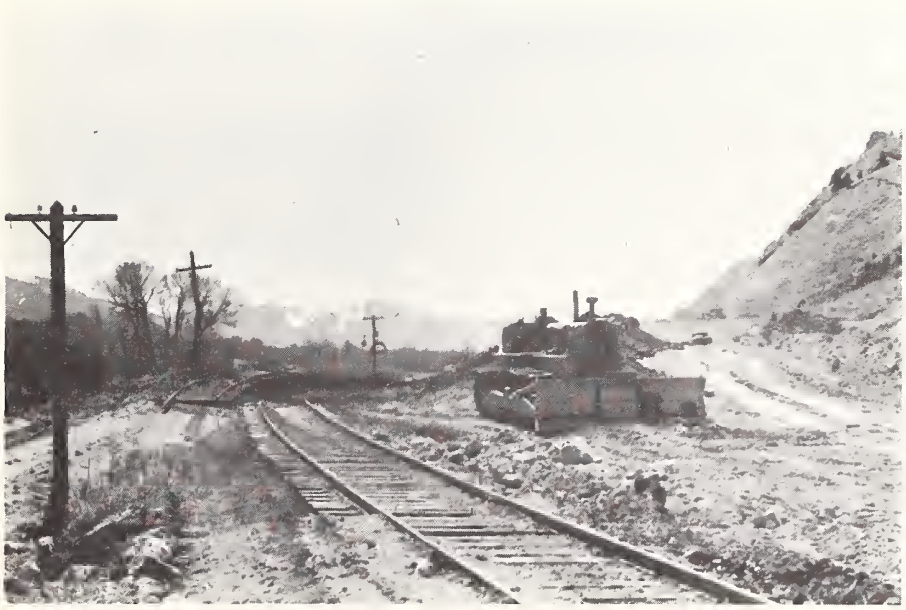
Oblique view toward north of failure, picture taken 4-27-65.



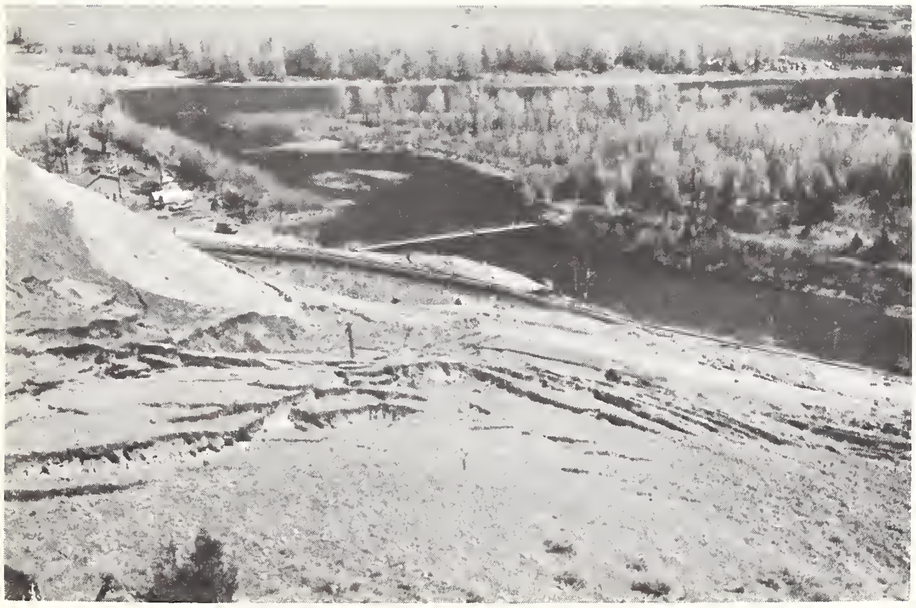
Oblique view toward west of failure, picture taken 4-27-65.



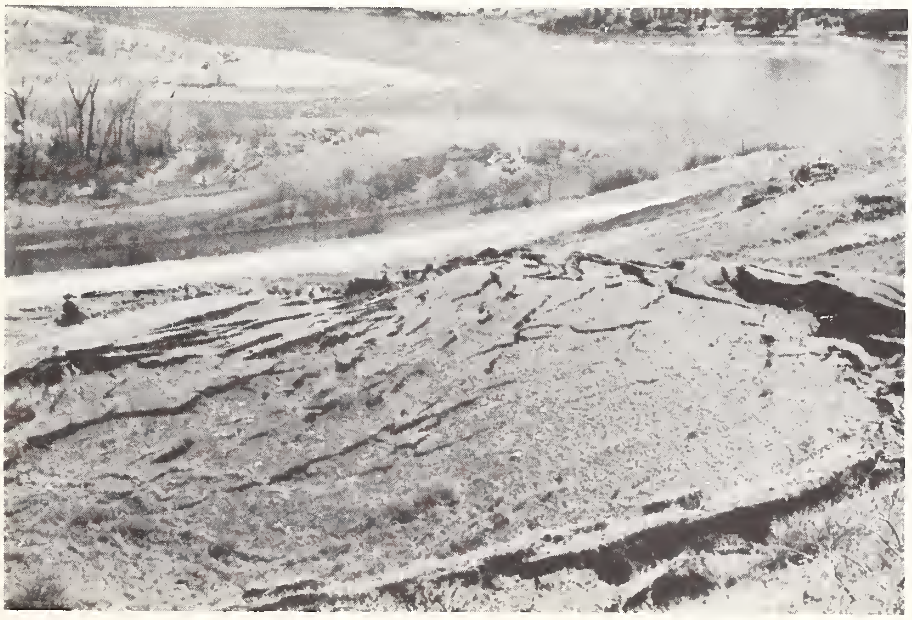
Railroad dislocation near south edge of failure zone. Picture taken April 22, 1965 looking north.



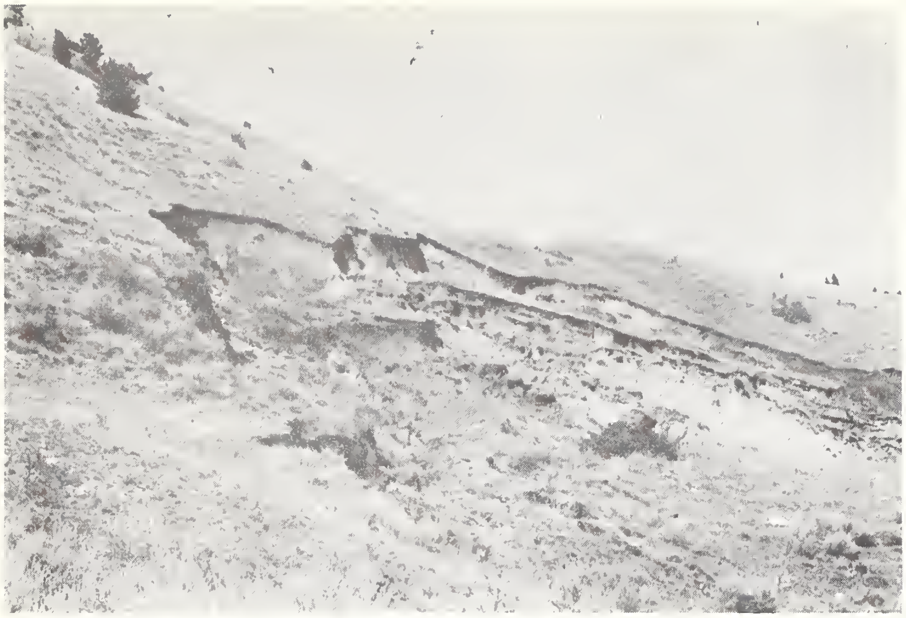
North end of railroad dislocation, picture looking south (4-22-65)



View from top of sliding mass toward the north east. Note diversion dam in the Yellowstone River which was threatened by one landslide. (4-27-65)

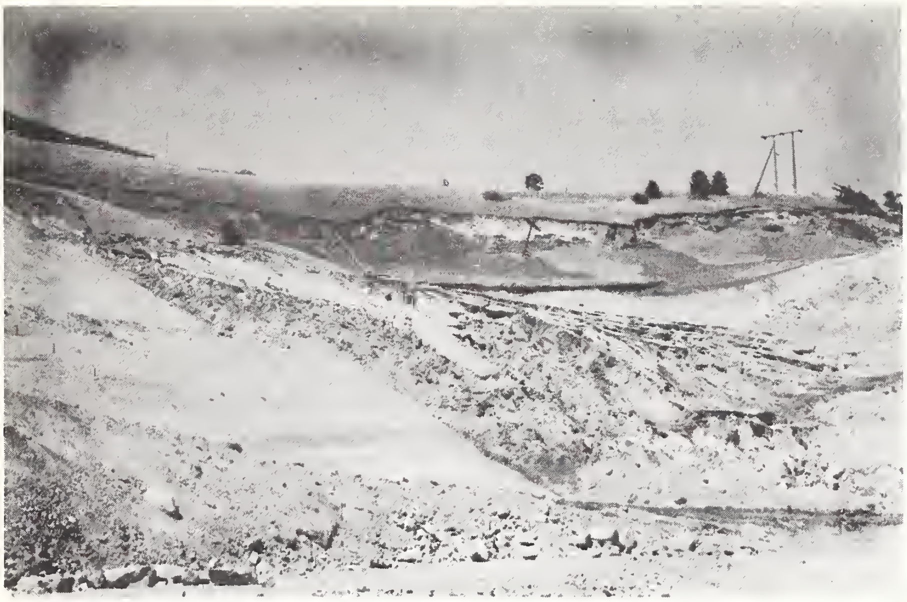


Central portion of the sliding mass, taken from the top scarp. Note bulge.

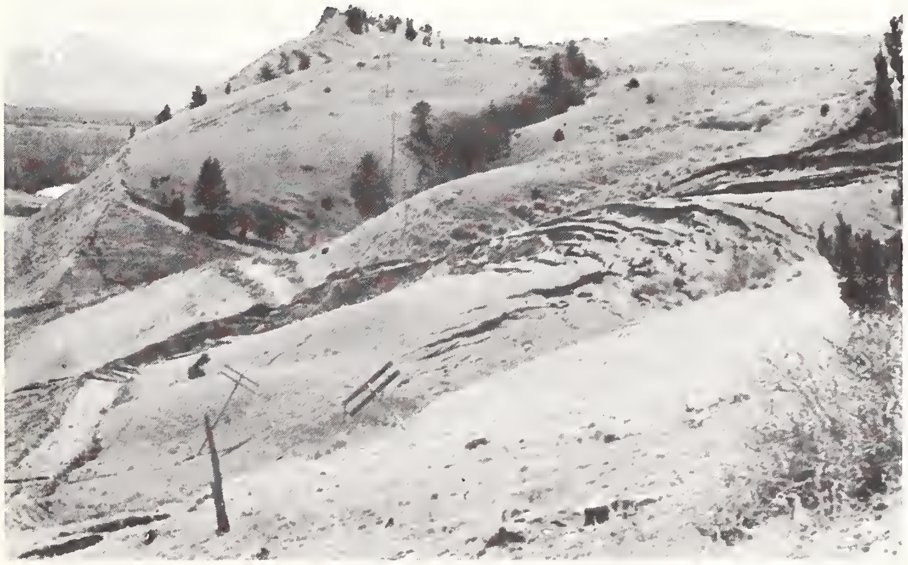


View looking north at the head of the slide. Note steepness of hillside above this initial failure. The head is creeping further to the left now.

View looking south of same area. (4-27-1965)



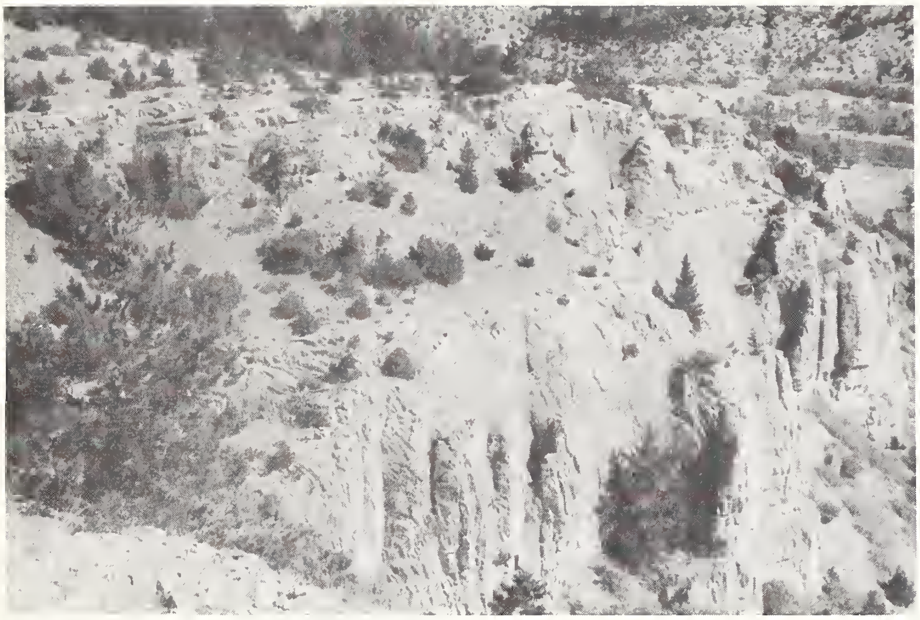
View across the middle of the landslide looking north from the railroad grade. (4-22-65)



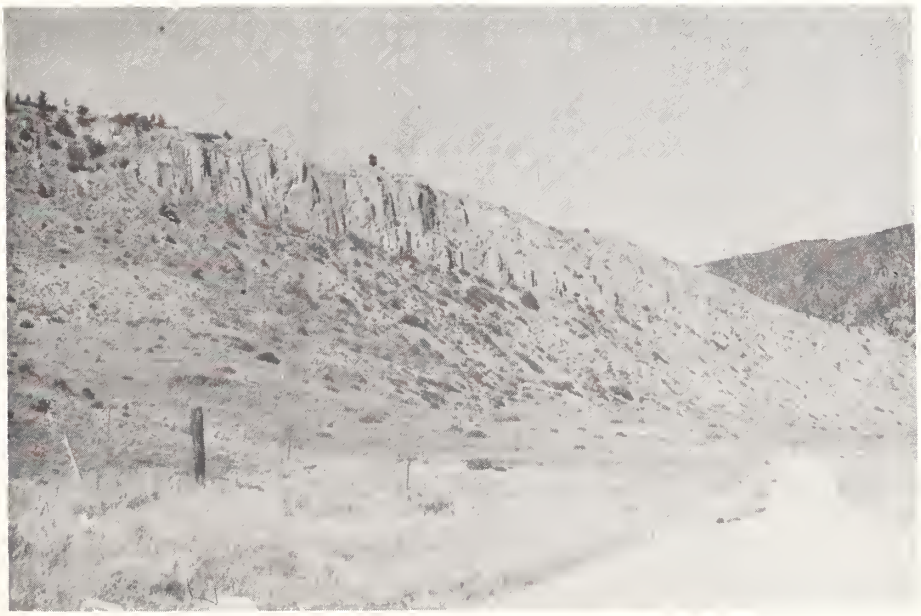
View across the middle of the landslide looking south from approx. elevation of the head.

Topography on the Landslide, note limestone rubble, size of slide blocks, poorly developed drainage. Taken near center of landslide area looking south.

Outcrop of Bighorn Dolomite, taken on north west edge of the landslide area.



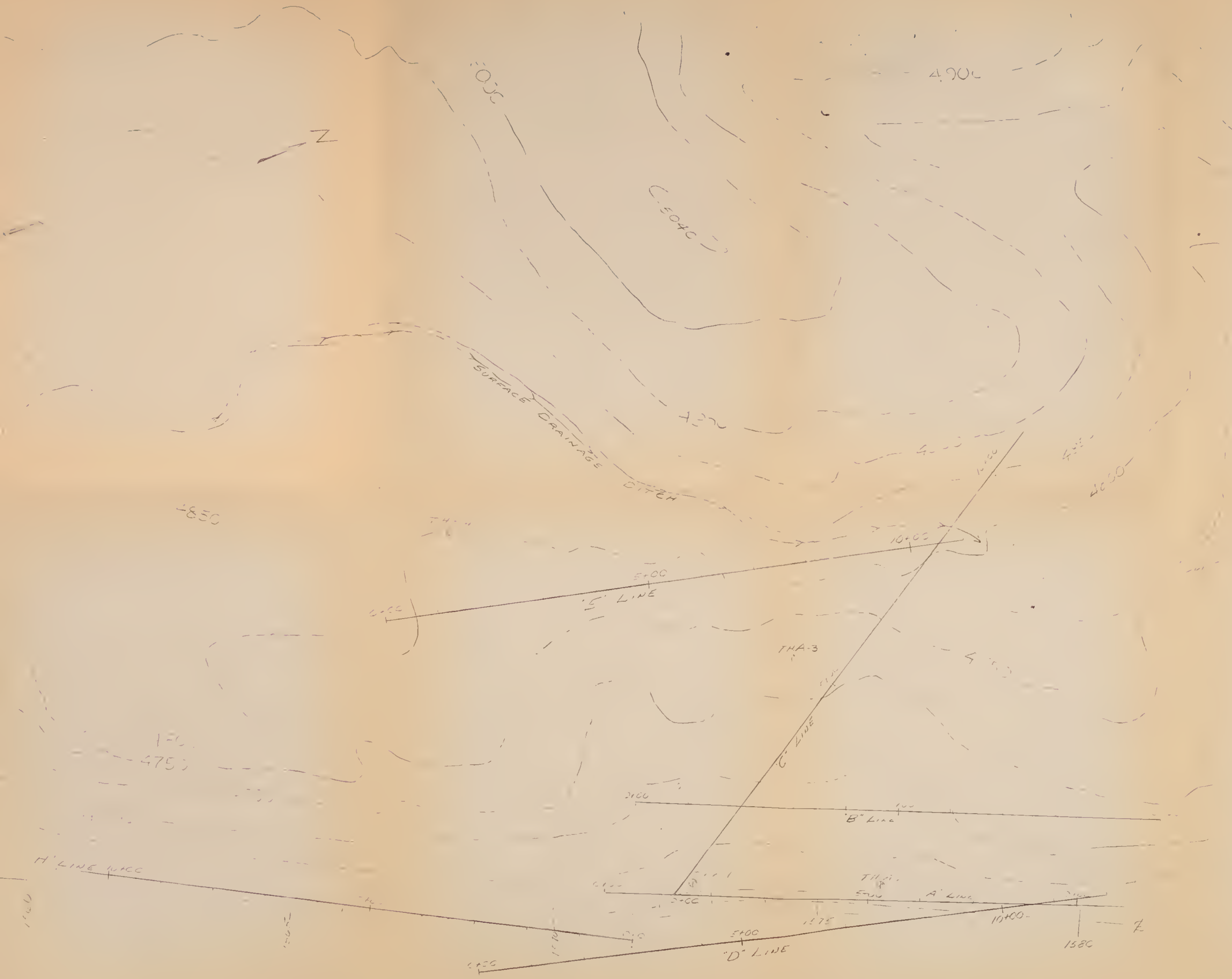
Outcrop of Pilgrim Limestone at north edge of Landslide Area, Normal Section.



Outcrop of Pilgrim Limestone at south edge of Landslide Area, overturned section.

PLATE I

LIVINGSTON LANDSLIDE
PROJECT H.F.R.-1(3)

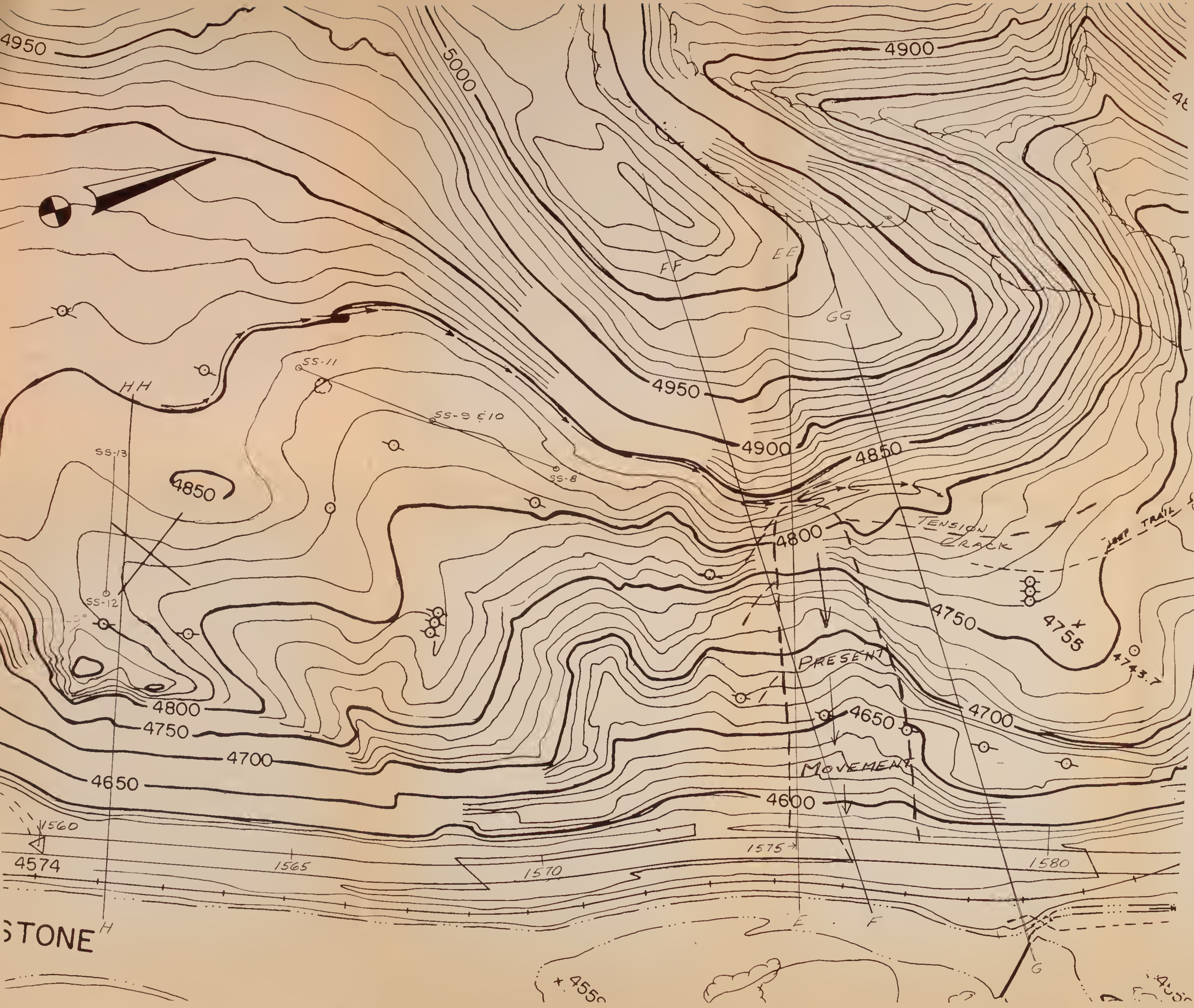


SCALE: [illegible]

Fold
Out

PLATE-2

LIVINGSTON
LANDSLIDE
H.P.R.-1(5)



LEGEND

SS- SEISMIC SHOT
H-HH-CROSS-SECTION
1575 - ℄ STATIONING

SCALE:
1 IN. = 100 FT.

PLATE 3

LIVINGSTON LANDSLIDE
PROJECT H.P.R.-1(5)

SECTION E-EE
LOOKING SOUTH

I.B.M. STABILITY ANALYSIS

ARC NO. 1 - SAFETY FACTOR = 0.558
" " 2 - " " = 1.046
" " 3 - " " = 0.901
" " 4 - " " = 0.757
" " 5 - " " = 0.737
" " 6 - " " = 0.786
" " 7 - " " = 1.143
" " 8 - " " = 1.101
" " 9 - NOT COMPUTED

SCALE: 1" = 50'

VALUES USED IN ANALYSIS
Unit Weight = 130 Lbs/Ft.^{3}
Ground Water Elev. = 4555'
Cohesion = 325 Lbs/Ft.^{2}
Ø = 15.0°

K&E STANDARD ● CROSS SECTION 10 × 10 TO THE INCH
KEUFFEL & ESSER CO. MADE IN U.S.A.
K&E STANDARD ● CROSS SECTION 10 × 10 TO THE INCH

PLATE A

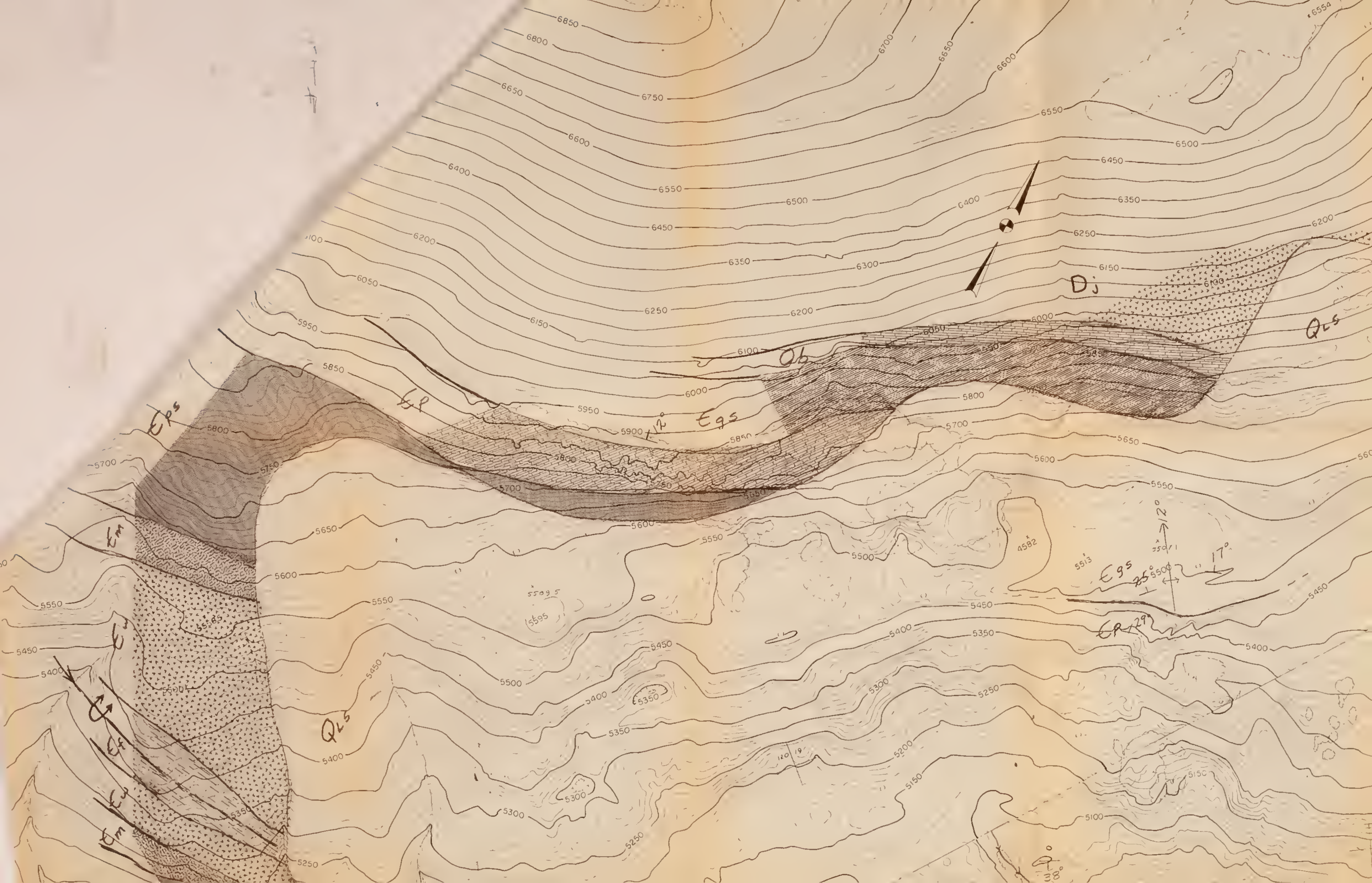
LIVINGSTON LANDSLIDE
PROJECT NO. H.P.R.-1(5)

SECTION G-GG
LOOKING SOUTH

I.B.M. STABILITY ANALYSIS:

ARC NO. 1 - SAFETY FACTOR = 1.241
" " 2 - " " = 1.151
" " 3 - " " = 1.330
" " 4 - " " = 1.227
" " 5 - " " = 1.438
" " 6 - " " = 1.177

SCALE: 1" = 50'
VALUES USED IN ANALYSIS:
Unit Weight - 130 Lbs/Ft.^{3}
Ground Water Elev. - 4555'
Cohesion = 325 Lbs/Ft.^{2}
$\phi = 20.0°$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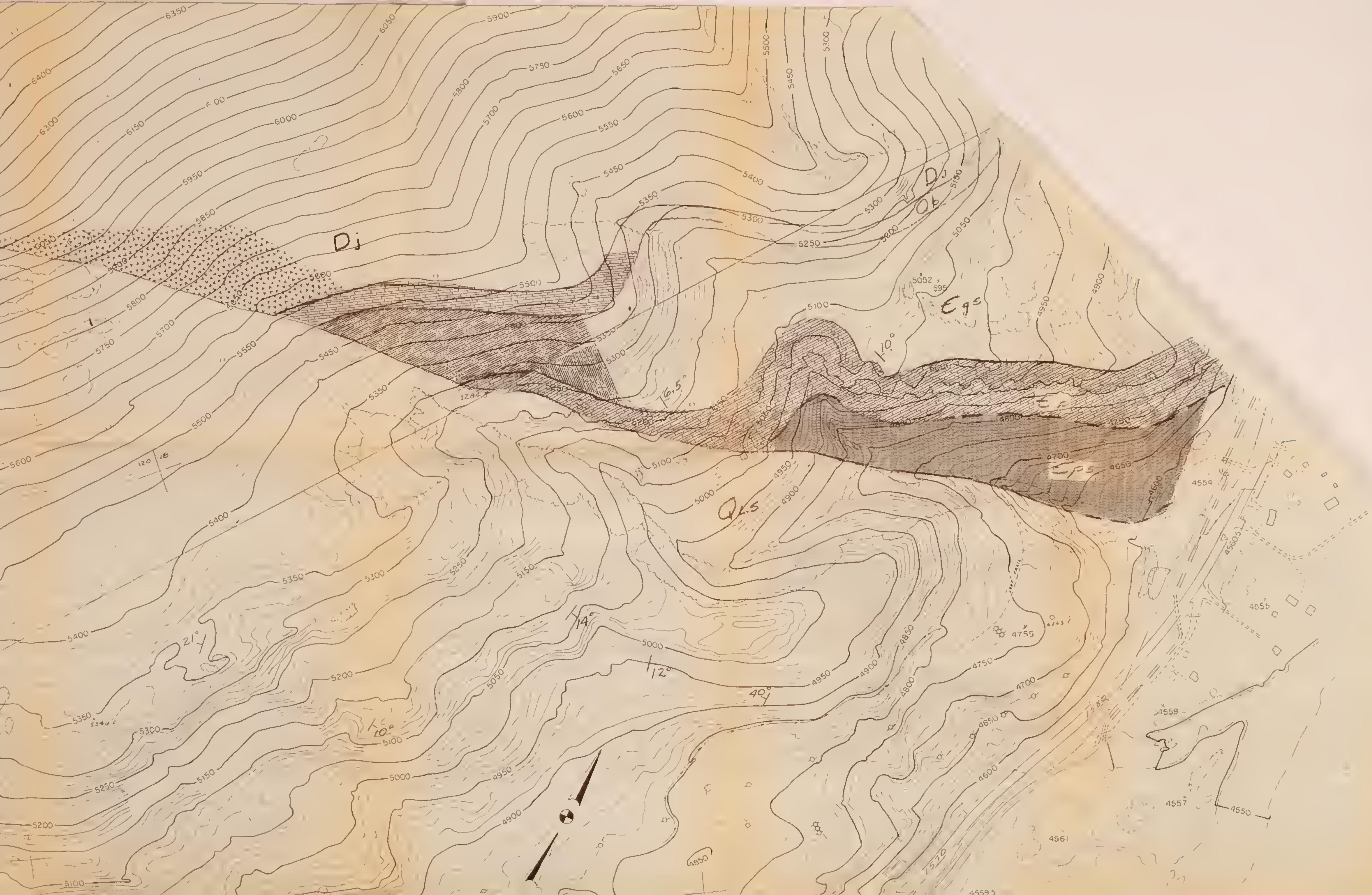
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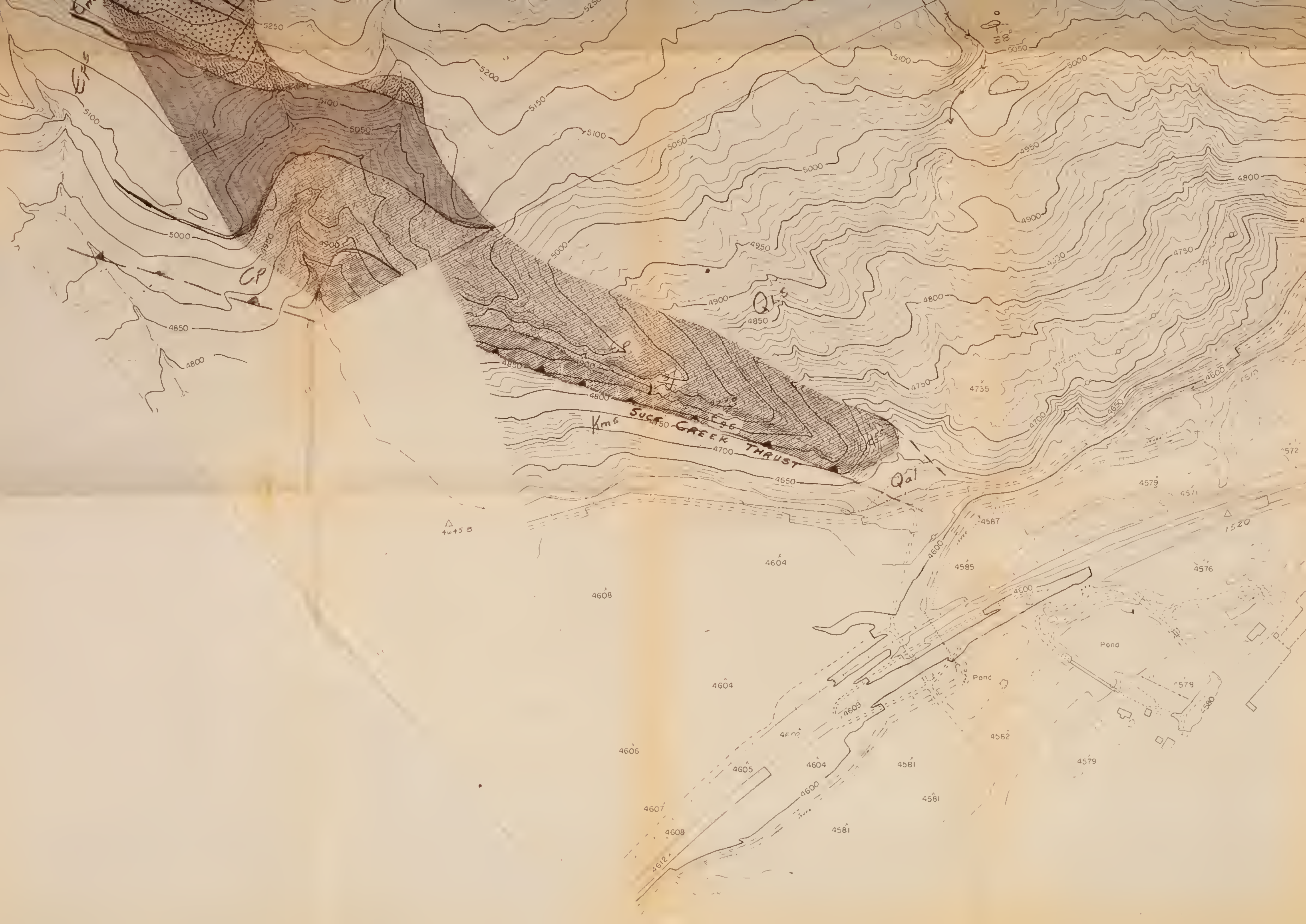

SUGAR CREEK THRUST
Kms
Qal
CR
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Pond
Pond
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5200
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5100
5050
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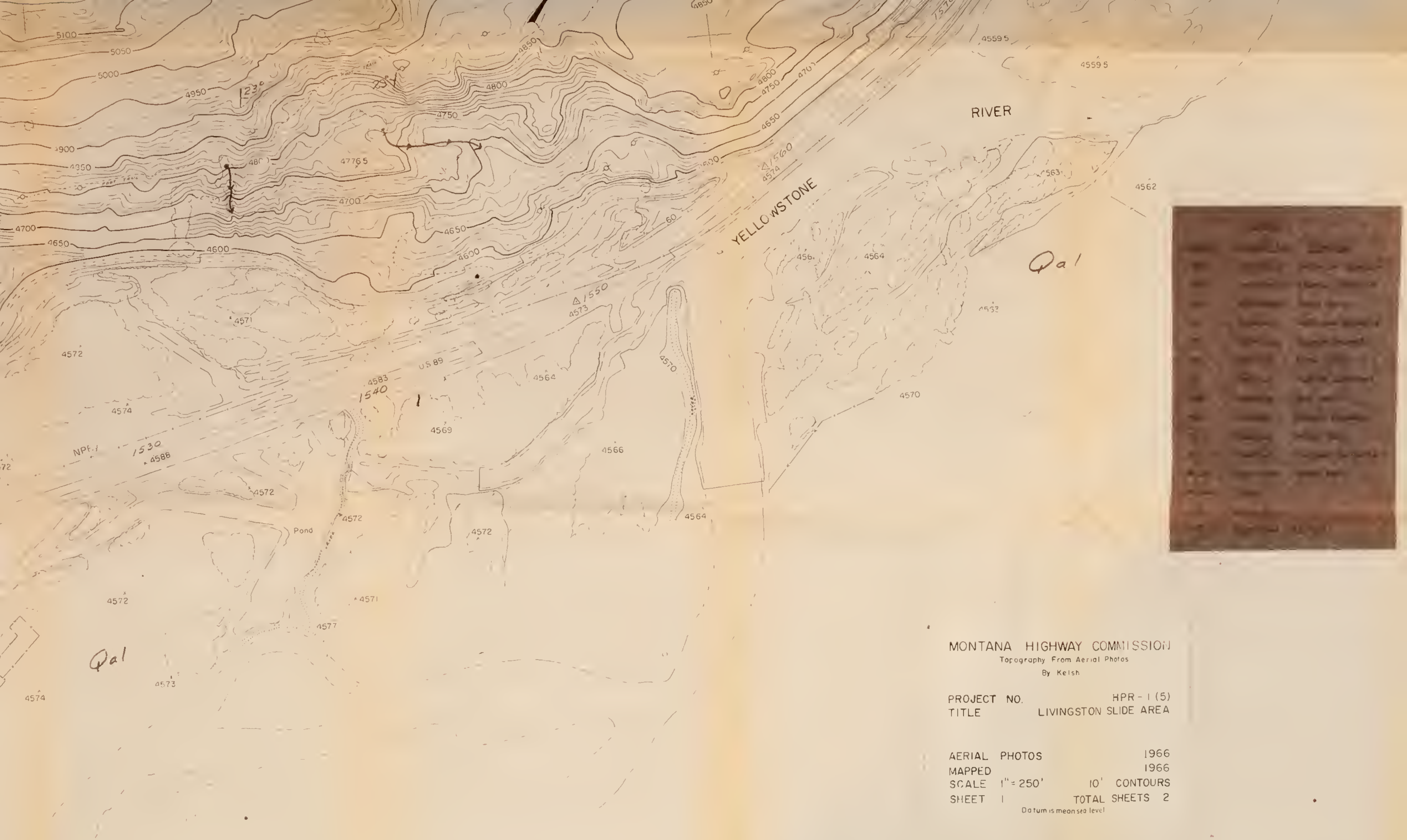

MONTANA HIGHWAY COMMISSION
Topography From Aerial Photos
By Kelsh

PROJECT NO.	HPR - 1 (5)
TITLE	LIVINGSTON SLIDE AREA
AERIAL PHOTOS	1966
MAPPED	1966
SCALE 1" = 250'	10' CONTOURS
SHEET 1	TOTAL SHEETS 2

Datum is mean sea level

State Highway Commission

Helena, Montana